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Abramson, Norman J. A probability sea survey plan for estimating relative abundance of ocean shrimp. 54 (4) : 257–269. 1968.

In the last formula on page 263, $\bar{y}_{hij}$ should be replaced by y_{hij}.

Calif. Fish and Game, 55 (1) : 4–11, 1969.

BIRD BANDING IN CALIFORNIA[1]

EMERSON A. STONER
Western Bird Banding Association
Benicia, California

Bird banding has been universally accepted as a very informative method of scientific study of many phases of wild bird biology. Government agencies recognize the value of such studies. In the United States, the U.S. Fish and Wildlife Service provides numbered bands and forms and instructions to encourage banding. The California Department of Fish and Game actively assists in the program and performs considerable record keeping, particularly with game birds.

More than 1,200,000 birds have been banded in California since the beginning of this activity in the early part of the present century. Although small in terms of percentage of birds banded, many banding recoveries and returns are now of record. Selected ones pertaining to California are reported herein.

INTRODUCTION

Bird banding as discussed here generally consists of the placement of a serially-numbered aluminum band on the leg of a wild bird. In the United States, such bands are supplied by the U. S. Fish and Wildlife Service. Bands range from size X (less than $\frac{1}{12}$ inch in diameter) designed for hummingbirds to size 9 (about $\frac{9}{10}$ inch in diameter) for eagles, herons, swans, and other large birds. A caption "Notify F. and W. Serv. Wash. D.C." appears on each band, and any finder of a bird wearing such a band should report the band number, species of bird, date and location where found, and other pertinent data such as cause of death, etc.

In Europe, Asia, and some other areas, this activity is called "ringing". Rydzewski (1965) reports that more than 30 million birds were "ringed" throughout the world from 1899 to 1963.

The California Department of Fish and Game cooperates with the U. S. Fish and Wildlife Service in authorizing and encouraging banding of wild birds to learn movements and migration routes, longevity periods, plumage changes, sex ratios, and other ornithological data. The California Fish and Wildlife Plan lists as its fourth objective "to provide for scientific and educational use of fish and wildlife" and proposes to insure the availability of fish and wildlife for study and research by scientists and students (California Department of Fish and Game, 1966).

Many state and federal personnel band birds in the performance of their official duties. The California Department of Fish and Game controls the issuance of state permits to individual students who band birds in California as a requirement of their educational curriculum and to others who can prove to the Department that they wish to band for scientific study purposes. Many persons authorized to band are volunteers and are not paid for their services. Much banding is done

[1] Accepted for publication September 1968.

in spare time by busy people who have a scientific interest in bird study. Both a California permit and a federal permit are required to capture migratory and insectivorous birds for banding. Birds may be detained only for the few minutes necessary to place the band and write the necessary data.

HISTORY

Several schemes for marking birds with numbered bands were projected in the early part of the present century. Lincoln (1947, p. 3) records that early interest in banding in the United States resulted in the organization of the American Bird Banding Association in 1909. In 1920, the work was transferred to the Bureau of Biological Survey (later incorporated in the U.S. Fish and Wildlife Service) and the Canadian Wildlife Service, which adopted uniform regulations.

A small group of southern California banders met in January 1925 at the call of J. Eugene Law of Altadena and formed the Western Bird Banding Association. The territory covered by the western association includes the 13 states of the United States wholly west of the 100th meridian, the three provinces of Canada wholly west of the 110th meridian, and Mexico west of the summit of the Sierra Madre Oriental.

Reports of birds banded in California are rendered annually to the California Department of Fish and Game, the Western Bird Banding Association, and periodically the U. S. Fish and Wildlife Service.

A total of 1,162,274 birds was banded in California from 1931 through 1966 (Table 1). These figures have been compiled from reports in the *Western Bird Bander*, official organ of the Western Bird Banding Association.

TABLE 1

Numbers of Birds of All Species Banded in California From 1931 Through 1966 *

Year	Total banded	Year	Total banded
1931	16,168	1951	34,278
1932	16,654	1952	37,785
1933	19,216	1953	50,673
1934	18,747	1954	43,159
1935	22,449	1955	58,310
1936	19,806	1956	70,617
1937	22,309	1957	63,533
1938	26,936	1958	66,449
1939	25,067	1959	46,597
1940	17,998	1960	44,240
1941	17,055	1961	35,088
1942	9,909	1962	46,201
1943	7,466	1963	53,040
1944	7,835	1964	49,798
1945	6,583	1965	51,710
1946	12,274	1966	62,466
1947	11,512		
1948	15,908	Grand total	**1,162,274**
1949	26,948		
1950	27,490		

* A review made by the writer of early files, reports, and publications indicates that between 80,000 and 100,000 birds were banded in California before 1931.

BIRD BANDING ACTIVITY IN CALIFORNIA DURING 1966

Reports to the Western Bird Banding Association show that 62,466 birds of 244 species were banded in 1966 by the 60 active California banding stations. Eighteen of the sixty active stations banded more than 500 birds during 1966 (Table 2).

TABLE 2

Banding Stations in California Which Banded More Than 500 Birds During 1966

Banding station or office	Total birds banded	Number of species
California Department of Fish and Game, Sacramento	11,790	7
Tule Lake National Wildlife Refuge, Tulelake	10,758	19
Point Reyes Bird Observatory, Bolinas	6,896	99
Alan M. and Jean T. Craig, San Diego	4,279	135
Paul Woronecki, Davis	4,274	6
S. W. Harris, Arcata	3,480	40
Salton Sea National Wildlife Refuge, Calipatria	3,370	12
Marianne R. Shepard, Glen Ellen	2,884	96
Don R. Roberts, Bakersfield	1,748	68
Thomas J. Harper, Fairfield	1,400	2
Emerson A. Stoner, Benicia	1,094	47
Charles H. Feltes, Modesto	1,002	40
L. Richard Mewaldt, San Jose	983	16
Henry E. Childs, Oakland	848	31
Don Bleitz, Hollywood	636	53
Arthur C. Felt, Whittier	603	32
Oakland Park Department, Oakland	570	12
D. Bruce Swinehart, Carmichael	568	26

The Point Reyes Bird Observatory (Table 2), established in 1965, is the only full-time banding station in America. This observatory, on the coast north of Bolinas, at the southern tip of Point Reyes National Seashore, promises to be very important to banders and bird enthusiasts because of the great diversity of birds found there. To date, 312 species of wild birds have been recorded for the Point Reyes Peninsula, which has been described as "the most exciting wildlife area in California".

Of the 244 species of birds banded in California in 1966, each of 24 were represented by more than 500 individuals (Table 3).

BANDING RECOVERIES AND RETURNS PERTAINING TO CALIFORNIA

It would not be possible, in a short article on bird banding, to publish all of the many significant and interesting reports of recoveries and returns of banded birds. Recoveries, in brief, refer to birds banded in one area and found, dead or alive, in another area. Returns, briefly, are birds banded at one station and recaptured subsequently at or near the same station.

Frank M. Kozlik, Waterfowl Coordinator for the California Department of Fish and Game, has at my request listed some of the banding recoveries of record in the Department of Fish and Game files (Appendix A). These are examples of movements of game birds banded in California and recovered outside the State.

TABLE 3

Species of Birds Over 500 of Which Were Banded in California During 1966

Species	Number banded in 1966
Pintail, *Anas acuta*	7,016
Mallard, *A. platyrhynchos*	6,745
Mourning dove, *Zenaidura macroura*	4,530
White-crowned sparrow, *Zonotrichia leucophrys*	4,250
Canada goose, *Branta canadensis*	2,995
House finch, *Carpodacus mexicanus*	2,766
Pine siskin, *Spinus pinus*	2,297
Green-winged teal, *Anas carolinensis*	2,265
Golden-crowned sparrow, *Zonotrichia atricapilla*	2,149
Brown-headed cowbird, *Molothrus ater*	2,056
Oregon junco, *Junco oreganus*	1,622
Leach's petrel, *Oceanodroma leucorhoa*	1,606
Starling, *Sturnus vulgaris*	1,530
American widgeon, *Mareca americana*	1,250
Band-tailed pigeon, *Columba fasciata*	1,117
Snow goose, *Chen hyperborea*	948
Tricolored blackbird, *Agelaius tricolor*	884
Audubon's warbler, *Dendroica auduboni*	856
Wilson's warbler, *Wilsonia pusilla*	817
American goldfinch, *Spinus tristis*	783
Cinnamon teal, *Anas cyanoptera*	646
Song sparrow, *Melospiza melodia*	639
Lesser goldfinch, *Spinus psaltria*	561
Cliff swallow, *Petrochelidon pyrrhonota*	523

Some additional recoveries and returns of both game and nongame birds were selected from reports made by various banders to the Western Bird Banding Association (Appendix B). These were selected with emphasis on interesting migration patterns and longevity records.

ACKNOWLEDGMENTS

I thank Frank M. Kozlik of Sacramento, Dorothy B. Hunt of Aptos, Charles H. Feltes of Modesto, Marjorie M. Elmore of San Jose, and many banders who have cooperated either by correspondence or personal contact.

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APPENDIX A

Selected Out-of-State Recoveries of Game Birds Banded in California

(Compiled by California Department of Fish and Game)

Species	Banding locality	Date banded	Recovery locality	Date recovered
Black brant, *Branta nigricans*	Humboldt Bay	Mar. 10, 1953	Eastern Siberia	June 5, 1953
Black brant	Humboldt Bay	Mar. 12, 1953	Novaya Sibir Island, East Siberian Sea	July 25, 1956
Lesser snow goose, *Chen hyperborea**	Tule Lake NWR†	April 8, 1952	Eastern Siberia	June 5, 1954
Lesser snow goose	Tule Lake NWR	April 14, 1952	Eastern Siberia	May 1955
Lesser snow goose	Tule Lake NWR	Nov. 2, 1952	Eastern Siberia	June 5, 1953
Lesser snow goose	Tule Lake NWR	Oct. 27, 1954	Eastern Siberia	June 8, 1956
Lesser snow goose	Tule Lake NWR	April 7, 1958	Eastern Siberia	May 31, 1961
Lesser snow goose	Tule Lake NWR	Mar. 16, 1959	Eastern Siberia	Sept. 13, 1959
Lesser snow goose	Tule Lake NWR	April 16, 1952	Wrangel Island	May 1956
Lesser snow goose	Tule Lake NWR	Oct. 26, 1958	Wrangel Island	Aug. 1959
Lesser snow goose	Tule Lake NWR	Mar. 16, 1959	Wrangel Isalnd	Aug. 1960
Lesser snow goose	Tule Lake NWR	April 1, 1959	Wrangel Island	June 1, 1961
Cinnamon teal, *Anas cyanoptera*	Honey Lake WA†	Aug. 31, 1951	Salvador	Nov. 6, 1951
Cinnamon teal	Imperial WA	Sept. 12, 1956	Ecuador	Dec. 14, 1956
Cinnamon teal	Los Banos WA	Sept. 8, 1961	Colombia	Nov. 26, 1961
Cinnamon teal	Los Banos WA	Sept. 8, 1961	Colombia	Nov. 26, 1961
Pintail, *Anas acuta*	Tule Lake NWR	Aug. 16, 1949	Cook Island, Pacific	Nov. 15, 1949
Pintail	Tule Lake NWR	Oct. 8, 1949	Eastern Siberia	May 28, 1956
Pintail	Tule Lake NWR	Aug. 13, 1955	Eastern Siberia	May 6, 1956
Pintail	Tule Lake NWR	Aug. 12, 1958	Phoenix Island, Pacific Ocean	Nov. 2, 1958
Pintail	Tule Lake NWR	Aug. 20, 1958	Eastern Siberia	May 25, 1963
Pintail	Tule Lake NWR	Aug. 28, 1961	Eastern Siberia	May 25, 1962
Pintail	Honey Lake WA	Aug. 18, 1951	Cook Island, Pacific Ocean	Nov. 30, 1952
Pintail	Honey Lake WA	Aug. 13, 1958	Eastern Siberia	Oct. 1959
Pintail	Gray Lodge WA	Sept. 1, 1954	Eastern Siberia	May 26, 1960
Pintail	Gray Lodge WA	Oct. 9, 1957	Eastern Siberia	Sept. 5, 1958
Pintail	Los Banos WA	Aug. 24, 1948	Near Tokelau Island, Pacific Ocean	May 29, 1955
Pintail	Los Banos WA	Aug. 21, 1955	Eastern Siberia	May 25, 1960
Pintail	Imperial WA	Sept. 25, 1953	Eastern Siberia	May 20, 1956
Pintail	Imperial WA	Sept. 29, 1956	Eastern Siberia	May 1963
Pintail	Grizzly Island WA	Oct. 16, 1956	Washington Island, Pacific Ocean	Dec. 13, 1956
Band-tailed pigeon, *Columba fasciata*	Pacific Grove	April 6, 1955	1 mi. E. of Reedsport, Ore.	Sept. 13, 1964
Band-tailed pigeon	French Gulch	Feb. 8, 1952	Forks, Wash.	Sept. 1960
Band-tailed pigeon	Bangor	Nov. 6, 1952	Vancouver Island, B.C.	Sept. 25, 1959
Mourning dove, *Zenaidura macroura*	Ridgecrest	Aug. 7, 1958	Ameca, Jalisco, Mex.	Feb. 1964
Mourning dove	Ridgecrest	Aug. 6, 1958	15 mi. W. of Phoenix, Ariz.	Dec. 19, 1964
Mourning dove	Gridley	May 31, 1961	Broadwater, Neb.	Apr. 1963
Mourning dove	Gray Lodge WA	July 27, 1959	Buckeye, Ariz.	Sept. 4, 1963
Mourning dove	Calipatria	July 22, 1958	Cocula, Jalisco, Mex.	July 1964
Mourning dove	Arvin	July 3, 1957	Cochise County, Ariz.	Sept. 6, 1964
Mourning dove	Mather AFB	July 5, 1957	Jalisco, Mex.	Oct. 1957
Mourning dove	Mather AFB	June 27, 1957	Aquililla, Michoacán, Mex.	Dec. 8, 1957
Mourning dove	Berkeley	Jan. 3, 1959	Jojutla, Morelos, Mex.	Jan. 23, 1959

* Frank M. Kozlik (pers. comm., 1967) stated that over 100 recoveries of snow geese banded at Tule Lake have been reported from Siberia and Wrangel Island by the Russians. In turn, the Russians started banding at Wrangel Island in 1960 and over 100 snow geese banded by them have been recovered in California.

† NWR = National Wildlife Refuge; WA = Wildlife Area (California); AFB = Air Force Base.

APPENDIX B

Selected Band Recoveries and Returns, Showing Longevities and Migrations of Various Species

(All Localities Are in California Unless Otherwise Indicated)

Species	Date banded	Date recovered or returned	Banding locality	Recovery or return locality
Canada goose *Branta canadensis*	7/ 5/55	9/19/63	Malta, Mont.	Tule Lake NWR*
Canada goose	6/30/60	12/25/62	Malta, Mont.	Bridgeport
Canada goose	6/28/56	12/21/56	Bear River Refuge, Utah	Sutter
Mallard, *Anas platyrhynchos*	9/ 8/40	12/23/56	Sacramento NWR, Willows	Fall River Mills
Mallard	11/28/48	12-1956	Havana, Ill.	Hamilton City
Pintail, *A. acuta*	1/16/31	9/30/43	Lake Merritt, Oakland	Lake Merritt, Oakland
Pintail	1/20/31	9/30/43	Lake Merritt, Oakland	Lake Merritt, Oakland
Pintail	12/ 7/36	12/22/45	Escondido	Escondido
Pintail	2/22/55	11/13/55	Near Honolulu, Hawaii	Butte City
Pintail	9/21/56	1-1957	Sacramento NWR, Willows	Culiacán, Sinaloa, Mex.
Pintail	7/31/60	1/ 5/63	Malta, Mont.	Merced
Green-winged teal *A. carolinensis*	1/22/58	8/ 9/63	Calipatria	Hebron, Colo.
Red-tailed hawk *Buteo jamaicensis*	5/20/27	8/21/32	Escondido	Escondido
Valley quail *Lophortyx californicus*	10/ 4/41	3/21/47	Healdsburg	Healdsburg
American coot *Fulica americana*	2/11/57	11-1958	Playa Del Rey, Mex.	Watsonville
Least sandpiper *Erolia minutilla*	9/19/46	6/13/47	Modesto	Nevada, Mo.
California gull *Larus californicus*	6/27/56	11/30/56	Aarod Lake, Mont.	Redondo Beach
California gull	6/28/59	7/ 7/61	Aarod Lake, Mont.	Fort Bragg
Ring-billed gull *L. delawarensis*	6/1960	9/16/60	Aarod Lake, Mont.	Big Bear Lake
Caspian tern *Hydroprogne caspia*	7/ 5/60	3/ 7/61	Humboldt Bay	San Blas, Nayarit, Mex.
Caspian tern	5/19/56	3/ 5/61	San Diego Bay	Playa Azul, Michoacán, Mex.
Band-tailed pigeon *Columba fasciata*	5/13/50	12/27/60	Cronin Point, Ore.	Nevada City
Band-tailed pigeon	7/20/53	10/16/59	Carmel	Carmel
Band-tailed pigeon	8/11/53	12/21/62	Carmel Valley	Near Carmel
Band-tailed pigeon	3/31/55	1/12/64	Carmel	Boulder Creek
Mourning dove *Zenaidura macroura*	7/22/57	9/18/57	Buena, Wash.	Calipatria
Mourning dove	7/14/58	9/27/58	Bow Bells, Burk Co., N. D.	Santa Maria
Mourning dove	1/30/58	9/ 1/58	Berkeley	Yakima, Wash.
Barn owl *Tyto alba*	4/24/35	10/28/46	Escondido	Escondido
Great horned owl *Bubo virginianus*	3/23/27	11/23/39	Benicia	Benicia
Ash-throated flycatcher *Myiarchus cinerascens*	6/18/60	2/18/61	Placerville	Colima, Mex.
Steller's jay *Cyanocitta stelleri*	11/23/58	7/28/63	Oakland	Oakland
Scrub jay *Aphelocoma coerulescens*	8/ 3/60	6/25/65	Paradise	Paradise
Scrub jay	11/ 1/59	2/12/66	Bakersfield	Bakersfield
Mountain chickadee *Parus gambeli*	9/ 1/43	8/31/49	San Bernardino Mountains	San Bernardino Mountains
Mountain chickadee	8/10/60	10/ 3/66	Idyllwild	Idyllwild
Mountain chickadee	7/ 1/60	9/ 6/66	Idyllwild	Idyllwild

APPENDIX B—Continued

Selected Bond Recoveries and Returns, Showing Longevities and Migrations of Various Species

(All Localities Are in California Unless Otherwise Indicated)

Species	Date banded	Date recovered or returned	Banding locality	Recovery or return locality
Chestnut-backed chickadee *P. rufescens*	7/22/57	1/18/61	Oakland	Oakland
Chestnut-backed chickadee	3/24/60	3/12/65	Santa Cruz	Santa Cruz
Plain titmouse *P. inornatus*	9/29/39	9/3/46	Altadena	Altadena
Plain titmouse	10/26/56	11/26/63	Bakersfield	Bakersfield
Plain titmouse	8/26/56	6/4/64	Sonoma	Sonoma
White-breasted nuthatch *Sitta carolinensis*	7/30/58	10/19/66	Idyllwild	Idyllwild
Red-breasted nuthatch *S. canadensis*	9/7/58	2/3/63	Oakland	Oakland
Bewick's wren *Thryomanes bewickii*	6-1939	1-1946	Pomona	Pomona
Mockingbird *Mimus polyglottos*	9/2/56	1/18/61	Benicia	Benicia
California thrasher *Toxostoma redivivum*	11/7/58	3/27/63	Oakland	Oakland
Robin *Turdus migratorius*	1/20/49	3/10/50	Benicia	Seattle, Wash.
Robin	12/14/57	8/10/63	Oakland	Brookings, Ore.
Robin	2/7/58	4/28/58	Sacramento	Castlegar, B.C.
Robin	3/9/58	1/16/62	Oakland	Lyndon, Wash.
Robin	7/28/59	2-1962	Vancouver Island, B.C.	Healdsburg
Robin	11/18/61	6/8/62	Modesto	Missoula, Mont.
Hermit thrush *Hylocichla guttata*	11/22/33	2-1942	Altadena	Altadena
Ruby-crowned kinglet *Regulus calendula*	11/28/59	1/1/65	Pendleton, Ore.	San Pedro
Cedar waxwing *Bombycilla cedrorum*	2/24/55	6-1955	Benicia	Auburn, Wash.
Cedar waxwing	2/12/46	8/10/47	Modesto	Longview, Wash.
Cedar waxwing	4/18/60	9/10/60	Whittier	Shell Lake, Sask.
Cedar waxwing	3/27/60	7/8/60	Benicia	Wenatchee, Wash.
Cedar waxwing	2/28/61	8/23/61	Benicia	Vancouver, B.C.
Cedar waxwing	3/11/64	7-1964	Modesto	North Vancouver, B.C.
Cedar waxwing	3/27/64	7-1964	Modesto	North Surrey, B.C.
Cedar waxwing	3/14/61	6/4/62	Sacramento	Battle Ground, Wash.
Starling *Sturnus vulgaris*	1/24/59	6/25/59	Sacramento NWR, Willows	Sangudo, Alta.
Orange-crowned warbler *Vermivora celata*	2/20/63	12/12/63	Santa Cruz	Isla de la Piedra, Mazatlán, Sinaloa, Mex.
Audubon's warbler *Dendroica auduboni*	10/28/60	12/24/60	Modesto	Long Beach
Audubon's warbler	12/9/60	2/11/66	Santa Cruz	Santa Cruz
Audubon's warbler	1/15/61	1/20/65	Sacramento	Sacramento
Brewer's blackbird *Euphagus cyanocephalus*	3/15/54	6/9/61	Benicia	Benicia
Brewer's blackbird	6/18/55	8/14/62	San Jose	San Jose
Brewer's blackbird	2/11/59	12/4/64	Benicia	Benicia
Brown-headed cowbird *Molothrus ater*	10/30/58	6/8/59	Willows	Pine Lake, Wash.

APPENDIX B—Continued

Selected Band Recoveries and Returns, Showing Longevities and Migrations of Various Species

(All Localities Are in California Unless Otherwise Indicated)

Species	Date banded	Date recovered or returned	Banding locality	Recovery or return locality
House finch	3/11/64	1/16/65	Modesto	Bakersfield
Carpodacus mexicanus				
House finch	2/ 9/65	4/ 5/65	Modesto	Diablo
House finch	2/ 7/53	3/16/64	Modesto	Modesto
House finch	2/28/54	1/10/61	Benicia	Benicia
House finch	8/23/51	2/ 6/61	Beverly Hills	Beverly Hills
Pine siskin	3/24/63	2/17/64	Seaside, Ont.	Modesto
Spinus pinus				
American goldfinch	4/ 8/59	7/ 2/59	Princeton	Whidbey Island, Wash.
S. tristis				
American goldfinch	2/25/61	6/29/61	Princeton	Portland, Ore.
American goldfinch	3/20/60	7/ 1/60	Princeton	Dayton, Ore.
American goldfinch	2/24/60	3/ 1/66	Princeton	Princeton
American goldfinch	4/23/59	10/15/59	Willows	Eugene, Ore.
Rufous-sided towhee	7/ 6/35	3/ 4/42	Altadena	Altadena
Pipilo erythrophthalmus				
Rufous-sided towhee	2/ 6/55	3/10/62	Oakland	Oakland
Rufous-sided towhee	2/22/56	4/14/61	Carmel Valley	Hines, Ore.
Brown towhee	3/20/52	3/ 6/61	Berkeley	Berkeley
P. fuscus				
Brown towhee	8/ 2/54	8/23/63	Santa Rosa	Santa Rosa
Brown towhee	12/12/54	3/24/63	Oakland	Oakland
Brown towhee	12/30/54	4/19/63	Carmel Valley	Carmel Valley
Brown towhee	7/ 8/35	4/ 8/45	Altadena	Altadena
Oregon junco	1/29/57	11/20/64	Sonoma	Sonoma
Junco oreganus				
Oregon junco	3/ 3/57	9/ 9/62	Oakland	Oakland
Oregon junco	1/17/58	10/29/63	Oakland	Oakland
Chipping sparrow	1/21/58	9/14/58	Escondido	Paradise
Spizella passerina				
White-crowned sparrow	8/26/59	12/31/61	Vancouver, B.C.	San Jose
Zonotrichia leucophrys				
White-crowned sparrow	9/10/61	6/ 5/66	Benicia	Everett, Wash.
White-crowned sparrow	1/28/62	8/19/62	San Jose	Bellingham, Wash.
White-crowned sparrow	3/26/62	5/12/62	San Jose	Port Angeles, Wash.
White-crowned sparrow	12/31/62	4/ 5/63	San Jose	Bainbridge Island, Wash.
White-crowned sparrow	4/17/63	5/10/64	Modesto	Stratford, Wash.
White-crowned sparrow	1/29/55	4/ 7/63	Sacramento	Sacramento
White-crowned sparrow	3/ 4/61	5/26/61	Benicia	Richmond, B.C.
White-crowned sparrow	4/10/53	7/ 1/55	Benicia	Oak Harbor, Wash.
White-crowned sparrow	9/18/59	11/ 7/59	Blaine, Wash.	San Jose
White-crowned sparrow	1-1960	5-1961	Santa Cruz	Skamakaway, Wash.
White-crowned sparrow	10/10/54	12/31/61	San Jose	San Jose
White-crowned sparrow	3/12/54	4/ 3/61	Benicia	Benicia
Golden-crowned sparrow	2/21/55	5/13/55	Berkeley	River Inlet, B.C.
Z. atricapilla				
Golden-crowned sparrow	11/15/53	11/ 5/61	Modesto	Modesto
Golden-crowned sparrow	11/30/52	3/ 3/62	Berkeley	Berkeley
Golden-crowned sparrow	10/15/55	3/17/62	Lafayette	Lafayette
Golden-crowned sparrow	11/17/56	1/15/63	San Rafael	San Rafael
Fox sparrow	1/ 6/57	11/17/62	Oakland	Oakland
Passerella iliaca				
Fox sparrow	11/ 5/60	1/30/66	San Rafael	San Rafael
Song sparrow	5/20/57	3/26/63	Oakland	Oakland
Melospiza melodia				
Song sparrow	7/ 4/52	1/24/61	Berkeley	Berkeley

* NWR = National Wildlife Refuge.

Calif. Fish and Game, 55(1) : 12–19. 1969.

AN EVALUATION OF STRIPED BASS ANGLING REGULATIONS BASED ON AN EQUILIBRIUM YIELD MODEL[1]

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An equilibrium yield-per-recruit model was used to examine the probable consequences of various changes in striped bass mortality rates. This analysis and an evaluation of striped bass mortality rates in Chesapeake Bay led to a conclusion that angling regulations could be varied over a wide range without endangering the population. Selection of regulations within this range must be based largely on social considerations, although the biological analysis demonstrates principles which should be considered in utilizing the population most effectively.

INTRODUCTION

A gradual decrease in sport fishing success for striped bass (*Roccus saxatilis*) during the late 1940's and early 1950's (Chadwick, 1962) caused considerable concern over the population's status. As a result, the daily bag limit was reduced from five to four fish in 1955 and then to three fish in 1956. Also, in 1956 the minimum size limit was increased from 12 to 16 inches.

This paper describes an evaluation of these angling regulations based on an equilibrium yield model of the population and mortality and survival rates. The mortality and survival estimates were derived from returns from about 18,300 striped bass tagged from 1958 through 1961. These returns indicated that the rate of exploitation ranged from about 0.19 to 0.37 and was most commonly about 0.25 from 1958 through 1964 (Chadwick, 1968). The survival rate in 1958 was about 0.32, but in subsequent years it ranged from about 0.51 to 0.66.

A concurrent attempt to estimate survival rates from creel census statistics failed because of annual variations in catchability (L. W. Miller and R. J. McKechnie, MS). Other measures of catch per unit of effort in the striped bass fishery are based on voluntary angler reports (Chadwick, 1962; R. J. McKechnie, MS). They are subject to too many sources of bias, error, and incompleteness to provide indices of stock and recruitment useful for a rigorous analysis of yield. Hence, there are neither independent estimates of mortality rates to serve as a check on the validity of estimates from tag returns, nor suitable measures of stock and recruitment, which are necessary to make a more complete analysis of yields than that presented in this paper.

The analysis described in this paper pertains to the striped bass population inhabiting the Sacramento-San Joaquin River system.

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[2] Now with Delta Fish and Wildlife Protection Study.

Essentially all striped bass fishing in California depends on this population.

METHODS

Equilibrium yields in numbers of fish harvested per given number of recruits at age 2 were calculated using formulas 1.4 and 1.8 (Ricker, 1958). Equilibrium yields in weight of fish per given number of recruits were estimated using the Beverton and Holt yield equation modified to allow the length-weight relationship to deviate from the cube law (Paulik and Gales, 1964).

Growth parameters for males and females were obtained from the von Bertalanffy growth curve (Abramson, 1965), using previously calculated striped bass growth rates (Robinson, 1960). Robinson's length-weight relationship is $\log W = -2.1393 + 3.0038 \log L$. Since the exponent 3.0038 differs so little from 3.0, yield estimates obtained with the unmodified Beverton and Holt equation would be essentially the same as those obtained here.

Mean weights of bass caught under the various conditions examined were determined by dividing estimated weight yields by estimated yields in numbers.

These estimates assume that:

1) Growth rates are constant over the range of stock densities resulting from assumed mortality rates.
2) Instantaneous natural mortality rates are constant from age 2 on despite varying exploitation rates and ages for starting harvesting.
3) All conditions are stable at least for a period equal to the life span of striped bass.
4) Mortality rates of males and females are equal.
5) Recruitment is independent of stock size over the range of conditions examined.

HYPOTHETICAL EQUILIBRIUM YIELDS

Equilibrium yields were compared for harvesting starting at ages 2, 3, and 4, with instantaneous fishing mortality rates ranging from 0.2 to 1.4. Comparisons were made for instantaneous natural mortality rates of 0.15, 0.25, and 0.35 (Figures 1, 2 and 3). Age 2 was the minimum age considered for starting harvesting because this is approximately the smallest (mean length about 10 inches) striped bass considered suitable for harvesting in most areas. Age 4 was considered to be the oldest age to which harvesting might realistically be delayed. The existing 16-inch minimum size limit results in recruitment to the fishery within a limited time when bass are about 3 years old.

While no one set of mortalities defines present conditions because of fluctuating mortality, an instantaneous fishing mortality rate of 0.30 and an instantaneous natural mortality rate of 0.25 are fairly typical of existing conditions (Chadwick, 1968, Table 9).

Increasing angling mortality 50 to 100% over the present rate would increase the catch in numbers substantially (Table 1). It would affect the weight yield little and might actually increase it. Mean weight would be reduced significantly and the catch of older, trophy-sized fish would be reduced greatly. For example, the catch of age 7 and older fish would be reduced 35 to 60%.

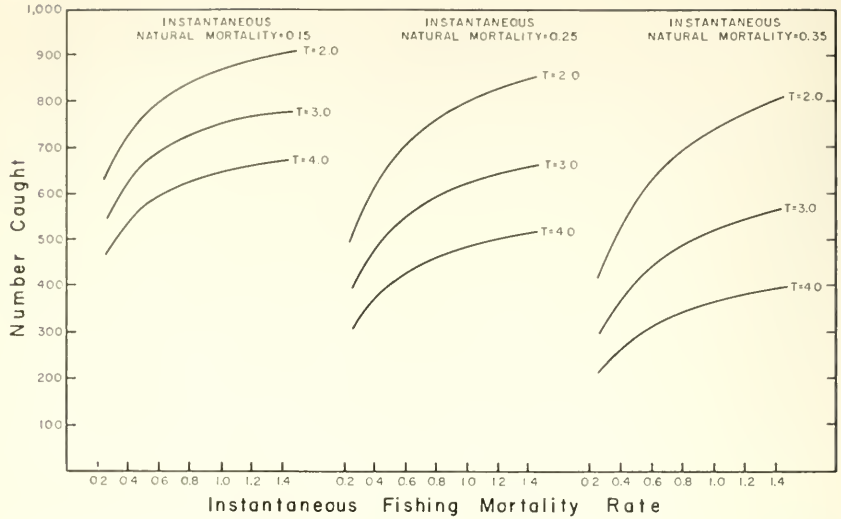

FIGURE 1—Steady-state theoretical yields in numbers for striped bass populations subjected to various instantaneous fishing mortality rates. Each population is assumed to have a constant instantaneous natural mortality rate and a constant recruitment of 1,000 fish at age 2. Populations are illustrated for three different instantaneous natural mortality rates and three different ages for the start of angling (T).

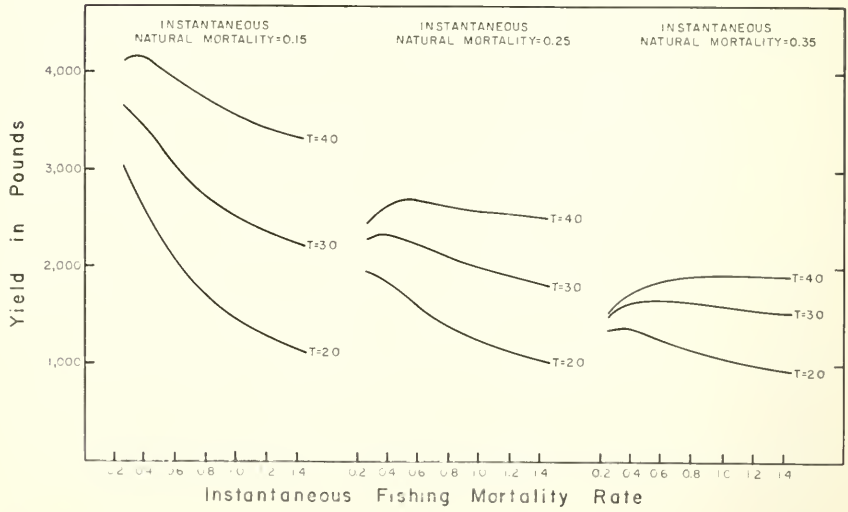

FIGURE 2—Steady-state theoretical yields in weight for striped bass populations subjected to various instantaneous fishing mortality rates. Each population is assumed to have a constant instantaneous natural mortality rate and a constant recruitment of 1,000 fish at age 2. Populations are illustrated for three different instantaneous natural mortality rates and three different ages for the start of angling (T).

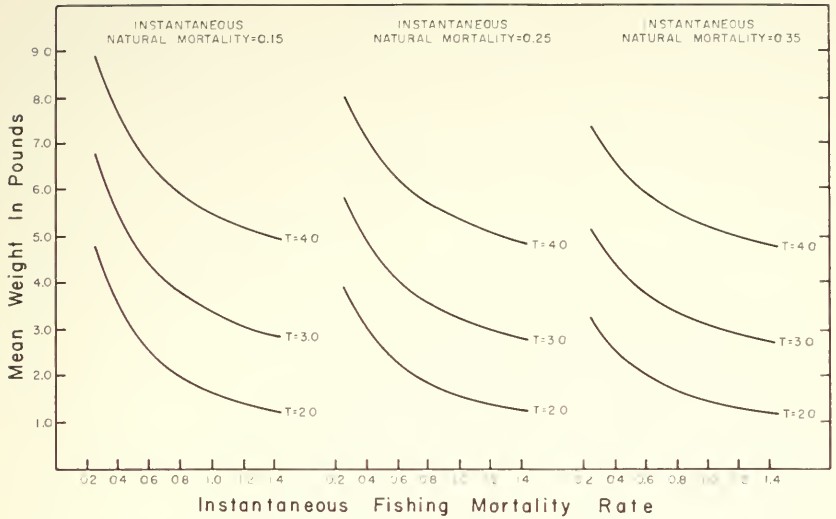

FIGURE 3—Mean weight of striped bass in catch for steady state striped bass populations subjected to various instantaneous fishing mortality rates. Each population is assumed to have a constant instantaneous natural mortality rate and a constant recruitment of 1,000 fish at age 2. Populations are illustrated for three different instantaneous natural mortality rates and three different ages for the start of angling (T).

TABLE 1

Theoretical Effects of Various Changes in Angling Mortality on Yields

Hypothetical condition			Percentage change from present condition*		
Age harvesting starts	Instantaneous angling mortality rate	Rate of exploitation	Number caught	Weight caught	Mean weight
3	0.45	0.32	+18	0	−16
3	0.60	0.40	+28	− 4	−26
3	0.75	0.47	+38	− 8	−34
2	0.30	0.23	+28	−16	−35
2	0.45	0.32	+51	−23	−50
2	0.60	0.40	+66	−31	−59
2	0.75	0.47	+76	−38	−65
4	0.30	0.23	−22	+ 9	+40
4	0.60	0.40	0	+16	+14

* Present instantaneous angling and natural mortality rates are assumed to be 0.30 and 0.25. Present age at which harvesting starts is age 3. Natural mortality and recruitment assumed to be constant throughout.

Even more substantial gains in numbers caught could be achieved by also starting to harvest bass at age 2 (about 10 inches long). However, this could be achieved only at the expense of significantly reducing total weight yield and reducing the mean weight 50% or more.

Delaying harvesting to age 4 would reduce numbers caught unless angling mortality were doubled. Delaying harvesting until age 4 without increasing the angling mortality rate would increase the weight yield about 10% by sacrificing about a fifth of the catch in numbers.

DISCUSSION

These hypothetical yields represent steady-state situations. Such a situation would never exist because mortality rates fluctuate due to factors independent of regulations, and because density independent factors would always cause variations in recruitment. However, they are useful approximations of average results.

As was pointed out earlier, a limitation of using these hypothetical yields to predict the effects of changing angling regulations is that they presuppose that recruitment is independent of spawning stock size. While the relationship between parent stock and recruitment cannot be defined for this striped bass population from available population measurements, an examination of its probable form is useful in evaluating the validity of this approach.

Ricker (1954) examined the relationship between parent stock and recruitment for various fish populations. Recruitment tended to be almost constant over broad ranges of parental stock size, presumably due to density dependent mortality among young fish. He found no population with maximum recruitment at a stock size equal to or greater than the equilibrium stock size (size at which recruitment equals parent stock). In general, recruitment was greatest at some stock size below the equilibrium one, and recruitment declined slightly as stock size increased. The relationships studied also implied that recruitment per parent was very high at low stock densities for populations in which many immature fish were harvested.

Recruitment per parent is probably very high at low stock densities for the striped bass population. The best evidence for this is the rapid increase in the population following its introduction into California. About 400 juvenile striped bass were introduced into the Sacramento-San Joaquin system in 1879 and by 1899 over a million pounds were harvested by commercial fishermen (Skinner, 1962). The very large 1934 year class produced in Chesapeake Bay by a relatively small parent stock (Raney, 1952) is also evidence of high reproductive potential.

Another pertinent consideration is that over much of the Delta young striped bass dominate the diet of older bass (Stevens, 1967; Thomas, 1967). This suggests that cannibalism is an important factor controlling recruitment, resulting in greatest recruitment when the adult stock is relatively small.

As a result, the variations observed in the amount of time adult bass spend in the Delta (Chadwick, 1967) undoubtedly change the shape of the stock-recruitment curve, with the slope of the right limb being directly related to the length of time adults spend in the Delta.

The sum of these factors leads to a hypothesis that the reproduction curve for striped bass in the Sacramento-San Joaquin system has a very steep left limb, a peak recruitment at a stock lower than the equilibrium stock without angler harvest, and a quite steep right limb due partly to cannibalism. Thus, recruitment would increase with angling mortality until angling reduced stock size below the point of maximum recruitment.

This deviation from the assumed independence of recruitment and spawning stock would cause the slopes of relationships between yields and angling mortality (Figures 1 and 2) to be more positive over the range of angling mortality where recruitment increased.

In summary, this steady-state population model indicates that numbers harvested could be increased substantially and the weight harvested could be maintained or increased slightly if angling mortality rates were increased 50 to 100%. This would cause a modest (perhaps 15 to 25%) reduction in the mean weight of fish caught, but a greater reduction in the catch of trophy-sized fish. One of the most likely deviations from the model, the hypothesized inverse relationship between recruitment and adult stock due to cannibalism, would cause the true gains to be greater than those predicted from the model.

The rapid establishment of striped bass after their introduction into California suggests that their reproductive potential is great enough to prevent such an increase in angler harvest from endangering the population. The effects of striped bass regulations in the Chesapeake Bay area also support this contention strongly.

In Chesapeake Bay actual tag returns in several studies in the 1930's ranged from about 30 to 40% in less than a year after tagging (Raney, 1952). More recently 38% of a group tagged in Maryland were returned (Mansueti, 1961) and 27% of a group tagged in Virginia were returned (Massmann and Pacheco, 1961). Most of these were recaptured within a year after tagging. The mortality rate indicated by these returns is difficult to determine because some tags increased the vulnerability of tagged fish to the commercial fishery (Lewis, 1961), tagging procedures varied, and nonresponse was not estimated. However, Mansueti (letter, 1962) believed that they indicate annual expectations of deaths from fishing ranging from 30 to 60%.

Minimum size limits there have ranged from 10 to 12 inches over the period. Roughly 60 to 70% of each year's catch are 2-year-old fish and about another 20% are 3-year-olds (Mansueti, letter, 1962). While this may be a somewhat biased indication of the population's age structure, it is certainly what would be expected considering the fishing mortality rates.

While the population there was relatively low during most of the 1930's and 1940's (Raney, 1952), Maryland commercial catches exceeded all previous catches each year from 1958 through 1961 (Maryland Board of Natural Resources, 1962). Catches per unit of effort in commercial and sport fisheries indicate that this reflected a real population increase (Mansueti, letter, 1962). Hence, the population there has maintained itself despite fishing rates higher than those in California and the harvesting of most fish before females become mature.

This evidence of a high reproductive potential and the maintenance of high yields in Chesapeake Bay indicates that the minimum size limit could be reduced to allow the harvesting of age 2 fish without endangering the population. This would undoubtedly greatly increase the catch in numbers at a substantial sacrifice in weight yield and mean weight of fish in the catch (Table 1).

Actually, reducing the minimum size limit would probably cause catch to increase and weight to decrease even more than suggested by this steady-state analysis. This would be true because 2-year-old striped bass would probably be more vulnerable to fishing, since they live all year in areas readily accessible to anglers. The high rate of exploitation found for small striped bass tagged in San Pablo Bay (Chadwick, 1968) supports this hypothesis.

On the other hand, delaying harvesting until age 4 would increase weight yields modestly while sacrificing numbers caught. This certainly would not endanger the population, but the sacrifice in numbers caught would be greater than indicated if the hypothesized importance of cannibalism is true.

This analysis leads to the conclusion that angling regulations could be varied within wide limits without endangering the striped bass population. The nature of the fishery, though, could be changed drastically by selecting various alternative regulations within these limits. In general, reducing the minimum size, or relaxing restrictions which limit harvest rates or both, would result in greater catches of smaller fish. More restrictive regulations would result in smaller catches of larger fish.

Since all alternatives are acceptable from a biological standpoint, selections must be based primarily on social considerations. While no absolute criteria are available for doing this, the 16-inch size limit appears to be a reasonable compromise. However, since this biological analysis indicates a moderate increase in harvest rates would increase numbers caught, probably without reducing the total weight of the catch significantly, serious consideration should be given to proposals for relaxing regulations, such as the recent removal of some restrictions on night fishing.

This analysis leads to the hypothesis that the striped bass population's apparent gradual decline in the 1940's and 1950's (Chadwick, 1962) was not caused by excessive angler catches. It is much more probable that it was due to deterioration in habitat. Thus, protection of the habitat should receive primary consideration in the future, particularly considering the major changes which are anticipated in the estuary.

ACKNOWLEDGMENTS

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OSMOREGULATION IN THE CALIFORNIA KILLIFISH, *FUNDULUS PARVIPINNIS*[1]

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The cyprinodont *Fundulus parvipinnis* inhabits estuaries and bays in California. Seventy specimens were captured and subjected to changing salinities over a period of 2 weeks. Results indicate that this species can osmoregulate over a wide range of salinities, from essentially fresh water to salinities approaching 70‰. A slight breakdown in osmoregulatory ability was noticed below 25‰ and a rapid breakdown above 65‰.

INTRODUCTION

There are over 20 species of *Fundulus* in the United States, but only one, *Fundulus parvipinnis*, occurs in California. Although it has been recognized for some time that the California killifish inhabits both fresh and salt water, little work has been undertaken to determine its salinity tolerance. Numerous researchers (Keys, 1931; Sumner and Fox, 1935; Wells, 1935a, 1935b; Doudoroff, 1945) have studied various aspects of this fish's physiology, but never its salinity tolerance limits or osmoregulation characteristics. In this study, we measure both and relate our findings to the fish's environment.

MATERIALS AND METHODS

Seventy specimens were collected in Goleta Slough, an estuary adjacent to the campus of the University of California, Santa Barbara. The specimens were arbitrarily divided into three groups: a control, those that would be maintained in hypersaline water, and those that would be maintained in hyposaline water. All fish were placed in three tanks (6.0 x 4.0 x 1.0 ft) and allowed to acclimate in normal sea water for a period of 2 weeks. This acclimation period was considered necessary because in some species of fishes held in captivity there is a period of laboratory diuresis resulting in a fatal loss of salts and water (Grafflin, 1931; Clarke, 1934; Brull and Nizet, 1953). A few of our fish died during the initial period, but we could not determine if this was a reaction to captivity or the result of injury during capture.

Following the acclimation period, the water in one tank was slowly replaced with tap water, the water in another was replaced with hypersaline water, and the third tank was left as a control. Hypersaline water was prepared by adding a large quantity of crystalline salt (obtained by complete evaporation of sea water) to sea water.

From the initial salinity of 34.13‰ ($\Delta - 1.86$ C) it took 13 days to raise the salinity to 69.78‰ ($\Delta - 3.80$ C) and 15 days to lower the

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salinity to 1.83‰ (Δ — 0.10 C). Blood samples were taken throughout this period. The tanks were constantly aerated and maintained at room temperature (20 C) under fluorescent lamps, with one end of each tank shaded. The fish were regularly fed fresh California mussel, *Mytilus californianus*.

Throughout the experiment we disturbed the fish as little as possible. They were not sorted for sex or size, and we only removed one or two from each tank every other day to obtain blood samples. After removal, the fish were inspected for possible physical abnormalities or injuries. If none was observed, the fish were placed on a small experimental board (Burke, 1962). One operculum was removed and a probe inserted to push the gill filaments anteriorly and expose the pericardial sac. The pericardium was then pierced with a scapel, severing the truncus arteriosus. Special care was taken not to injure the heart, which would cease beating if damaged. Blood that emptied into the pericardial cavity was collected in 50 λ capillary tubes. Four blood samples were collected from either one large or two small fish in each of the experimental tanks. The samples were immediately frozen on dry ice. The solute concentration of the blood was obtained by allowing the four samples to melt, and using the sample with the lowest freezing point. This method tended to minimize disruptive influences caused by lymph, interstitial fluids, or coagulation that may have contaminated the sample. The apparatus and techniques for determining freezing point depression are those described by Gross (1954).

RESULTS

In normal sea water, the freezing point of California killifish blood is Δ — 0.78 C, a value similar to those reported by others for selected marine teleosts (Table 1).

TABLE 1

Freezing Points for the Blood of Selected Marine Teleosts in Various Environments

Family Species	External environment (△ C)	Blood (△ C)	Reference
Salmonidae			
Chinook salmon, *Oncorhynchus tshawytscha*	−1.92	−0.76	Greene, 1904
Anguillidae			
American eel, *Anguilla rostrata*	−1.85	−0.82	Smith, 1932
European eel, *Anguilla anguilla*	seawater	−0.78	Portier and Duval, 1922
Congridae			
Conger eel, *Conger conger*	−1.70	−0.70 to 0.79	Dekhuyzen, 1905
Gadidae			
Cod, *Gadus virens*	−1.73	−0.76	Dekhuyzen, 1905
Cottidae			
Longhorn sculpin, *Myoxocephalus octodecimspinosus*	−1.85	−0.82	Smith, 1932
	seawater	−0.72	Forster, 1953
Shorthorn sculpin, *Myoxocephalus scorpius*	seawater	−0.71	Forster, 1953
Lophiidae			
Goosefish, *Lophius piscatorius*	seawater	−0.77	Brull and Cuypers, 1954
	seawater	−0.67	Forster, 1953

The salinity of our artificial environments changed from roughly three-quarters (Δ — 1.25 C) to approximately double (Δ — 3.60 C) that of sea water with only a Δ — 0.77 to Δ — 0.84 C change in the blood concentration of the killifish (Figure 1). As the salinity decreases from Δ — 1.25 C, the freezing point of the blood decreases fairly rapidly in comparison with the osmoregulatory plateau between Δ — 1.25 and Δ — 3.60 C. Initially the change is quite rapid but it soon levels off. The change for blood in this part of the curve is Δ — 0.18 C for an environmental change of Δ — 1.15 C. The osmoregulatory curve never reaches 0.00 C. The discrepancy between 0.00 and Δ — 0.10 C. is apparently due to the incomplete replacement of salt water and the extreme "hardness" of the tap water in Santa Barbara.

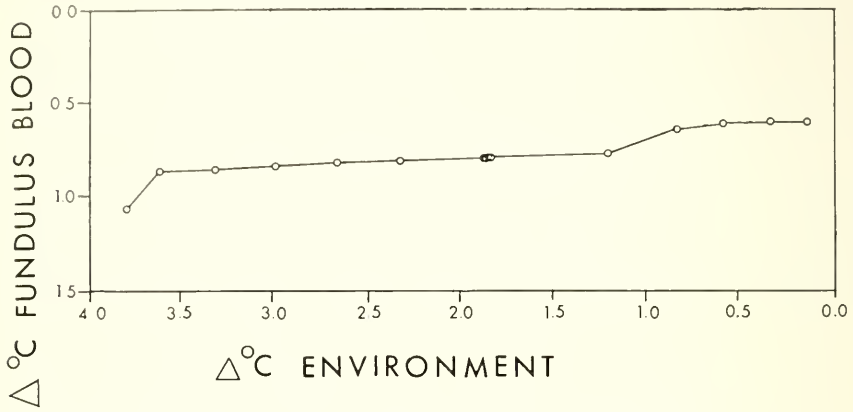

FIGURE 1—Osmoregulatory curve far California killifish, *Fundulus parvipinnis*. Note the extensive plateau, which probably corresponds to this fish's normal environmental salinity range.

Perhaps the most interesting portion of the curve is between Δ — 3.60 and Δ — 3.80 C. Between these salinities there is a rapid loss of osmoregulatory ability; the freezing point of the blood is depressed from Δ — 0.84 to Δ — 1.09 C. At this particular point only two fish remained alive in the hypersaline tank. This, of course, indicated a very rapid breakdown in osmoregulatory ability due to overtaxing the normal channels of salt excretion and secretion, to drastically interfering with metabolic processes, or to both.

DISCUSSION

The California killifish is admirably equipped to survive in its brackish habitat. Goleta Slough, where our specimens were caught, is a shallow body of estuarine water averaging 2 to 3 ft deep at mean low tide. The slough receives fresh water from rain runoff in the winter, agricultural draining in the summer, and some partially treated domestic effluent. California killifish are found both inside and outside the slough during the entire year, but they exhibit a preference for waters inside the slough, which may be closed off from the ocean most of the year by a sand bar across the entrance. Keys (1931) collected over

5,000 killifish in San Diego and Mission Bays and states that they prefer protected areas to the open ocean and exhibit little evidence of migrations between bays.

Black (1957) noted that marine teleosts with glomerular kidneys have a blood concentration of "approximately $\Delta = 0.78$ C", the same freezing point we observed in this experiment. Leövey (1938) believed that salt concentrations much greater than sea water ($\Delta = 2.85$ to $\Delta = 3.00$ C) are eventually fatal to marine teleosts. A survey of the literature on euryhaline species may lead one to believe that either greatly elevated salinities or salinities approaching fresh water are fatal to these fish. However, in many of the past experiments, *Fundulus* have been subjected to extreme osmotic shock by taking them directly from normal sea water and placing them in waters of higher or lower salinities. In such cases mortality rates from 20 to 95% have been reported. The fact that the California killifish shows yearly fluctuations in its tolerance to decreased salinities introduces further confusion. During the breeding season there is a selective mortality, with the females dying at a far greater rate than the males (Keys, 1931).

Summer (1906) concluded "*F. majalis* failed to reveal any selective mortality in relation to size among fishes dying from the effects of fresh water. Such a selective mortality was very obvious, on the other hand, in the case of asphyxiation, the eliminated set having an average length about 7% greater than the surviving set (i.e., those last to die)."

Since we conducted our experiments during October and November (not the breeding season), kept the fish well fed (other experimenters generally starved their fish for a number of days before experimentation), handled the fish as little as possible, kept them well aerated and at a constant temperature, and slowly increased and decreased the salinities, we believe that we eliminated many of the factors which may have affected other osmoregulation experiments with fishes.

The area primarily responsible for salt regulation consists of the Keys-Willmer cells located in the gills. Keys and Willmer (1932) calculated that there are three to six million chloride secreting cells in the gills of a 250-g eel.

Fish best able to tolerate rapid change in salinity and low oxygen tensions are those with large heads in proportion to their standard lengths (Keys, 1931). This is apparently a function of the gill area size and the number of Keys-Willmer cells available for oxygen and salt transfer per units of body weight. Burnes and Copeland (1950) found that the mummichog, *F. heteroclitus*, has supplemental Keys-Willmer cells in the oral, pharyngeal, and opercular epithelium. Since the mummichog and the California killifish are both euryhaline and are closely related, the California killifish also may have supplemental chloride cells.

Recent work on three species of *Fundulus* (Philpott, 1963) further elucidates the function of these chloride secreting cells. The mummichog was adapted to fresh and salt water. In saltwater adapted specimens, the chloride secreting cells were like those of the stenohaline saltwater dwelling longnose killifish, *F. similis*. When the mummichog was then adapted to fresh water, the cells changed appearance and approximated those of the stenohaline freshwater golden topminnow, *F. chrysotus*.

In all three species, the chloride-secreting cells have a cytoplasm that is heavily populated with mitochondria and filled with tubules of the agranular endoplasmic reticulum. The main difference between freshwater and saltwater adapted cells is the hypertrophy of various intracellular elements, particularly "the apical vesicle and apical crypt, which are rarely present in fresh water adapted *Fundulus*" (Philpott, 1963).

The slight decrease in the blood freezing point between $\Delta -1.25$ and $\Delta -0.10$ C also was observed by Keys (1931) in California killifish, and by Black (1957) in numerous other fishes. This drop in blood freezing point is primarily due to a loss of blood chloride and an influx of water which results in an increase in the fish's weight. On the other hand, the rapid increase in freezing point depression at elevated salinities has never been reported. By analogy, this must be the result of dehydration, which would increase the relative proportion of salts in the blood. We have no idea how long fish exposed to salinities greater than $\Delta -3.60$ C would survive because the fish that remained alive at $\Delta -3.80$ C had to be sacrificed to obtain blood samples. Perhaps the sharp increase in freezing point indicated the imminent death of the fish. These fish were smaller than the average, perhaps indicating that the increased head body ratio is just as important in maintaining salt balance at elevated salinities as it is at decreased salinities.

CONCLUSIONS

Fundulus appears to contain homio-osmotic euryhaline species of essentially marine origin (Pickford, 1953). We found nothing to disprove this theory and the great tolerance to osmoregulatory stress seems to support this view. Not only did the fish survive, but they reacted quite normally—feeding, swimming, and reacting to noises until the salinity reached about $\Delta -3.60$ C, when they became lethargic. Certainly this value approaches their maximum tolerance to elevated salinities.

The osmoregulatory curve (Figure 1) for California killifish, *Fundulus parvipinnis*, demonstrates:

1. A stable solute concentration in the blood over a wide salinity range, $\Delta -1.25$ to $\Delta -3.55$ C. In these salinities the fish can osmoregulate with little difficulty.
2. A slow drop in solute concentration in the blood between $\Delta -1.25$ and $\Delta -0.10$ C, which the fish can probably tolerate indefinitely.
3. A very rapid rise in solute concentration of the blood ($\Delta -3.60$ to $\Delta -3.80$ C). This indicates a breakdown in osmoregulatory capacity with an influx of salt and an efflux of dilute body fluids that results in death.

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RESULTS OF A SIX-YEAR TRAWL STUDY IN AN AREA OF HEAVY WASTE DISCHARGE: SANTA MONICA BAY, CALIFORNIA[1]

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A trawl study was conducted in Santa Monica Bay, an area of large-scale waste disposal, during the years 1958–1963. It was hoped that information on the occurrence and distribution of bottomfish in this area would reveal the effects of waste disposal on their populations. In all, 705 bottom tows in 60 to 600 ft of water yielded 112,799 fish of 104 species plus a number of unidentified juvenile rockfish. Five species made up the bulk of the catch. There was a moderately high yield of fish per tow in 1958, an extreme low in 1959, a buildup in 1960, a high in 1961, and a moderate drop in 1962 and 1963.

It was impossible to show that fluctuations in abundance, as measured by trawl catches, were the result of waste discharge in the study area, and not due to natural causes.

The sport catch for the years 1958 through 1963 in Santa Monica Bay showed only small fluctuations.

Artificial reefs in Santa Monica Bay offered evidence that giant kelp was unable to survive in areas affected by the "fallout" of particulate matter from waste discharges, and possibly from turbidity from the same source.

INTRODUCTION

In September 1957 the Bureau of Sanitation, City of Los Angeles, and the California Department of Fish and Game entered into an informal agreement to conduct a trawl study as part of a continuing surveillance program for Santa Monica Bay. The purpose of this program is to evaluate the effects on the marine environment of the waste discharges from the Hyperion Treatment Plant. This plant discharged effluent varying from 261 to 283 million gal a day during the 6 years of the study. Solids discharged by the sludge line ranged from 130 to 156 tons per day.

The City of Los Angeles provided the boat, equipment, and crew, and the Department of Fish and Game provided the biologists, to conduct the study. It was hoped that information on the occurrence and distribution of bottomfish in Santa Monica Bay would reveal the effects of waste disposal on their populations. In the past, attempts to prove and document the long-term and subtle influence of major waste discharges on the open coastal biotope have invariably met with frustration and failure (Ludwig and Omodera, 1964). Six years of trawling on a quarterly basis from 1958 through 1963 provided a large quantity of data.

This paper deals principally with the trawl data for Santa Monica Bay. However, work dealing with marine habitat development (Carlisle, Turner, and Ebert, 1964) and the sport-fish catch for the years 1958 through 1963 in Santa Monica Bay also are discussed, since they are pertinent to the overall problem of pollution of the area.

[1] Accepted for publication May, 1968.

METHODS

Trawling operations were conducted from the *Prowler,* a 65-ft converted salmon troller used in the Santa Monica Bay monitoring program. Trawling equipment included a winch powered by the main engine and an A-frame on the fantail, through which a single cable led over a block to the trawl net. A 25-ft cable bridle was attached to a pair of small otter boards fixed to short lines on the wings of the net. The boards were 12- by 18-inch steel-reinforced plywood, heavily weighted along the bottom. The net was a 24-ft semiballoon or try net with a body of 1½-inch mesh, number 18 twine. During the study, there was some variation in bags. Originally, a liner of ¼-inch webbing was used to catch small invertebrates, but large amounts of debris were retained. Therefore, we changed to a liner of ½-inch mesh synthetic material, which made little difference in fish catches.

A series of 39 regular stations in depths of 60 to 600 ft was trawled each quarter (Figure 1). While difficulties in scheduling the boat and crew made it impossible always to adhere to the quarterly program, it was followed as closely as possible.

Each trawl was for 10 min, clocked from the time the net was on the bottom (and fishing) until the winch was started and net retrieving began. All fish caught in each haul were sacked and labeled by consecutive haul number. Shelled mollusks were counted or their numbers were estimated and they were either returned to the water or preserved for later identification.

Surface and bottom temperatures and dissolved oxygen readings were taken at all stations. The monitoring program also included chloride and coliform samples from some stations.

All fish taken in the trawl were taken back to the laboratory and examined. A record was kept listing haul number, date, depth of water from which taken, fish weight, length, and sex for each species. In large catches, subsamples were taken, and the remainder counted and their size range recorded. Notations were made on maturity, stomach contents, parasites, and evidence of disease or abnormalities (Appendix).

DISCUSSION

In March 1964, a faster vessel, the *Marine Surveyor,* replaced the *Prowler.* Because this vessel trawled at a faster speed, it was impossible to compare catch data with previously obtained information. With this development, and since we had enough data for a sound evaluation, we decided to conclude the study as of the last quarter of 1963.

In 1958, only two of the months in the period from November to March are represented, and in 1961 data from only 3 months out of the 7-month period, April through October, are available. However, it appeared that sampling was adequate to indicate any major fluctuations in bottomfish populations.

During the study, 112,799 fish of 104 species plus unidentified juvenile rockfish were taken in 705 hauls (Table 1). Twenty species made up 96% (108,872 individuals) of the total catch and were represented in all hauls. The other 84 species were represented by 3,922 individuals. Because the northern anchovy, *Engraulis mordax,* is a pelagic species, the 16,247 taken (10,000 in one haul in 1958) were not considered in the analysis. Only 15 species were represented by more than 1,000 individu-

als and only 35 species by more than 100 individuals during the 6 years. Many species were taken only once or twice.

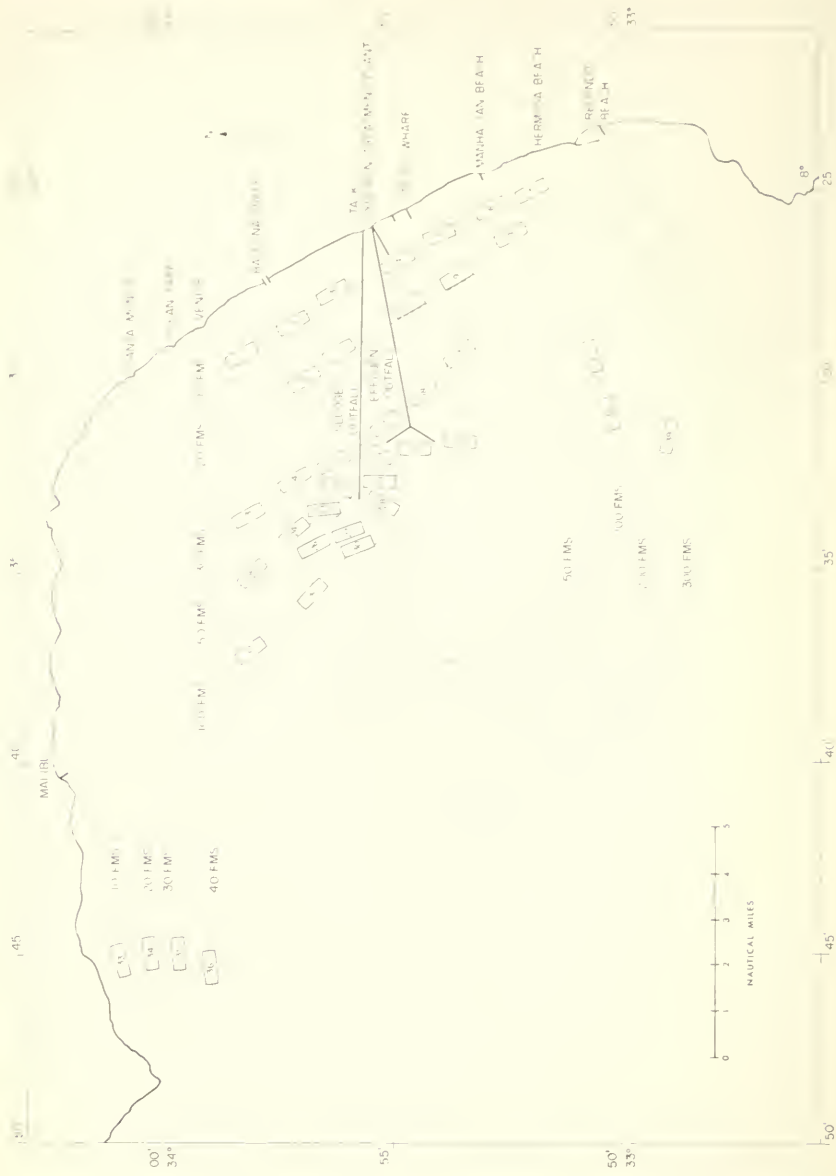

FIGURE 1—Santa Monica Bay trawl stations and locations of the effluent and sludge lines which carry the Hyperion Treatment Plant waste discharge.

Five species of fishes were taken in such numbers (83,713 or 74% of the total catch) and with such consistency that my evaluation of the

TABLE 1

Fishes Trawled in Santa Monica Bay From the *Prowler* From 1958 Through 1963

Common name	Scientific name	Number
Speckled sanddab	*Citharichthys stigmaeus*	30,581
Yellowchin sculpin	*Icelinus quadriseriatus*	23,791
California tonguefish	*Symphurus atricauda*	10,438
Plainfin midshipman	*Porichthys notatus*	10,314
Slender sole	*Lyopsetta exilis*	8,589
English sole	*Parophrys vetulus*	4,178
Pacific sanddab	*Citharichthys sordidus*	3,803
Dover sole	*Microstomus pacificus*	3,274
White croaker	*Genyonemus lineatus*	2,138
Pink seaperch	*Zalembius rosaceus*	2,036
Blacktip poacher	*Xeneretmus latifrons*	1,466
Hornyhead turbot	*Pleuronichthys verticalis*	1,368
Blackbelly eelpout	*Lycodopsis pacifica*	1,332
Stripetail rockfish	*Sebastodes saxicola*	1,249
Pigmy poacher	*Odontopyxis trispinosa*	1,169
Calico rockfish	*Sebastodes dalli*	842
Queenfish	*Seriphus politus*	778
Bigmouth sole	*Hippoglossina stomata*	584
Shortspine combfish	*Zaniolepis frenata*	509
Splitnose rockfish	*Sebastodes diploproa*	433
Greenspotted rockfish	*Sebastodes chlorostictus*	323
Bay goby	*Lepidogobius lepidus*	264
Rex sole	*Glyptocephalus zachirus*	253
Specklefin midshipman	*Porichthys myriaster*	241
Bluespotted poacher	*Xeneretmus triacanthus*	216
Spotfin sculpin	*Icelinus tenuis*	207
Longspine combfish	*Zaniolepis latipinnis*	204
Shiner perch	*Cymatogaster aggregata*	178
Curlfin turbot	*Pleuronichthys decurrens*	147
Pacific argentine	*Argentina sialis*	124
Halfbanded rockfish	*Sebastodes semicinctus*	119
Fantail sole	*Xystreurys liolepis*	111
Longfin sanddab	*Citharichthys xanthostigma*	111
Pacific hake	*Merluccius productus*	106
Basketweave cusk-eel	*Otophidium scrippsi*	105
Vermilion rockfish	*Sebastodes miniatus*	89
Bluespot goby	*Coryphopterus nicholsi*	88
Pipefish	*Syngnathus* spp.	88
California halibut	*Paralichthys californicus*	87
C-O turbot	*Pleuronichthys coenosus*	86
White seaperch	*Phanerodon furcatus*	80
Spotted cusk-eel	*Otophidium taylori*	63
Sculpin	*Scorpaena guttata*	55
Sarcastic fringehead	*Neoclinus blanchardi*	49
Greenstriped rockfish	*Sebastodes elongatus*	46
Bonehead sculpin	*Artedius notospilotus*	38
Petrale sole	*Eopsetta jordani*	30
Slender sculpin	*Radulinus asprellus*	28
Spiny dogfish	*Squalus acanthias*	26
Unidentified juvenile rockfish	*Sebastodes* spp.	26
Flag rockfish	*Sebastodes rubrivinctus*	23
Southern spearnose poacher	*Agonopsis sterletus*	23
Smooth ronquil	*Rathbunella hypoplectus*	21
Fringed sculpin	*Icelinus fimbriatus*	19
Pacific electric ray	*Torpedo californica*	18
Rubberlip perch	*Rhacochilus toxotes*	16
Cow rockfish	*Sebastodes levis*	16
Thornback	*Platyrhinoidis triseriata*	14
Black perch	*Embiotoca jacksoni*	14
Ratfish	*Hydrolagus colliei*	13
Shortbelly rockfish	*Sebastodes jordani*	11
Pile perch	*Rhacochilus vacca*	10
California lizardfish	*Synodus lucioceps*	9
Pacific pompano	*Palometa simillima*	9
Roughback sculpin	*Chitonotus pugetensis*	9

TABLE 1—Continued

Fishes Trawled in Santa Monica Bay From the *Prowler* From 1958 Through 1963

Common name	Scientific name	Number
Dark-blotched rockfish	*Sebastodes crameri*	8
Shovelnose guitarfish	*Rhinobatos productus*	8
Brown rockfish	*Sebastodes auriculatus*	8
Smooth stargazer	*Kathetostoma averruncus*	8
Starry rockfish	*Sebastodes constellatus*	7
Sandpaper skate	*Raja kincaidi*	6
Walleye surfperch	*Hyperprosopon argenteum*	6
Kelp bass	*Paralabrax clathratus*	6
Sand bass	*Paralabrax nebulifer*	6
Spotted turbot	*Pleuronichthys ritteri*	5
Mexican rockfish	*Sebastodes macdonaldi*	5
Shortspine channel rockfish	*Sebastolobus alascanus*	3
Horn shark	*Heterodontus francisci*	3
California skate	*Raja inornata*	3
Painted greenling	*Oxylebius pictus*	2
Bearded eelpout	*Lyconema barbatum*	2
Pacific angel shark	*Squatina californica*	2
Bluebarred prickleback	*Plectobranchus evides*	2
Smoothgum eelpout	*Aprodon cortezianus*	1
Red brotula	*Brosmophycis marginata*	1
Bocaccio	*Sebastodes paucispinis*	1
Honeycomb rockfish	*Sebastodes umbrosus*	1
Chilipepper	*Sebastodes goodei*	1
Rainbow seaperch	*Hypsurus caryi*	1
Sablefish	*Anoplopoma fimbria*	1
Cabezon	*Scorpaenichthys marmoratus*	1
Giant kelpfish	*Heterostichus rostratus*	1
Northern spearnose poacher	*Agonopsis emmelane*	1
Swell shark	*Cephaloscyllium ventriosum*	1
Grey smoothhound	*Mustelus californicus*	1
Diamond turbot	*Hypsopsetta guttulata*	1
Pacific ocean perch	*Sebastodes alutus*	1
Sharpchin rockfish	*Sebastodes zacentrus*	1
Longspine channel rockfish	*Sebastolobus altivelis*	1
Olive rockfish	*Sebastodes serranoides*	1
Threadfin sculpin	*Icelinus filamentosus*	1
Grunt-sculpin	*Rhamphocottus richardsoni*	1
Whitebarred blenny	*Poroclinus rothrocki*	1
Whitebelly rockfish	*Sebastodes vexillaris*	1

catch data is based mainly on them. These key species are: speckled sanddab, *Citharichthys stigmaeus;* yellowchin sculpin, *Icelinus quadriseriatus;* California tonguefish, *Symphurus atricauda;* plainfin midshipman, *Porichthys notatus;* and slender sole, *Lyopsetta exilis.*

When the catch per haul of the species is compared with the catch per haul of all fish taken on a yearly basis, their dominance is clearly indicated as well as the trend from a moderately high yield in 1958, a severe drop in 1959, a buildup in 1960, a high for the period in 1961, and a moderate drop in 1962 and 1963 (Figure 2).

The speckled sanddab showed a similar population trend (Figure 3). The mean catch per haul of speckled sanddabs was high in 1958, dropped to a low in 1959, showed a buildup in 1960, a high for the 6-year period in 1961, and dropped down somewhat in 1962 and 1963. A positive attraction of this species to the nutrient-enriched area near the sludge outfall (7 miles offshore) is evident during the last 3 years

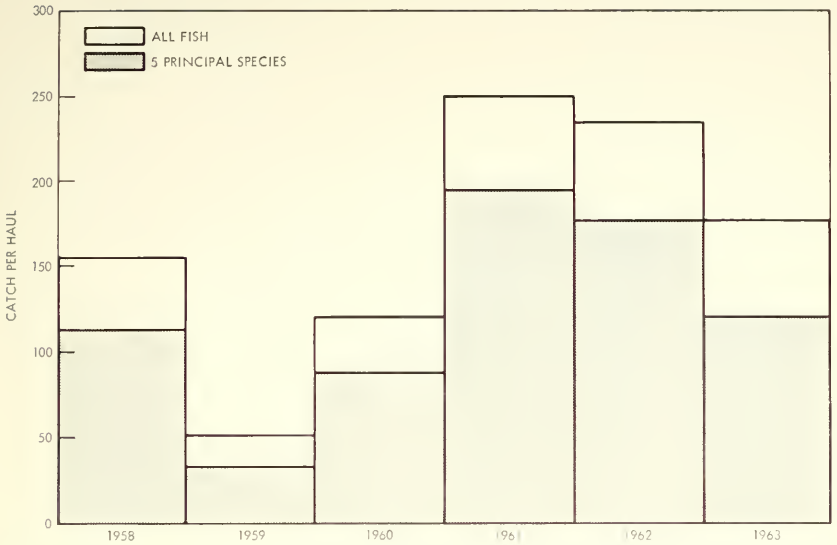

FIGURE 2—Catch per haul of the five principal species, speckled sanddab, yellowchin sculpin, California tonguefish, plainfin midshipman, and slender sole, compared with that of all species combined.

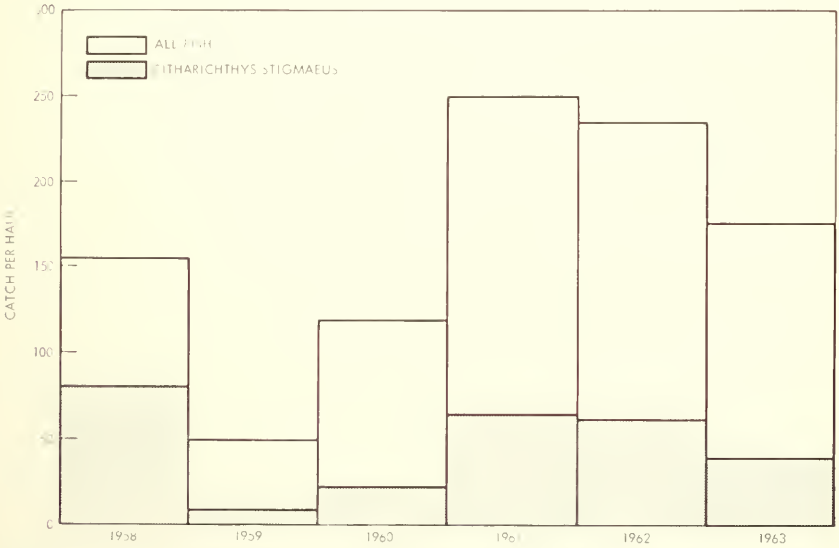

FIGURE 3—Speckled sanddab catch per haul compared with that of all species combined.

of the study, perhaps as the sludge accumulated (Figure 4). An increased catch of speckled sanddabs was evident at Stations 22, 28, and 29 when compared with the more remote Stations 23, 24, and 25. Speckled sanddabs avoided the effluent area (Figure 5).

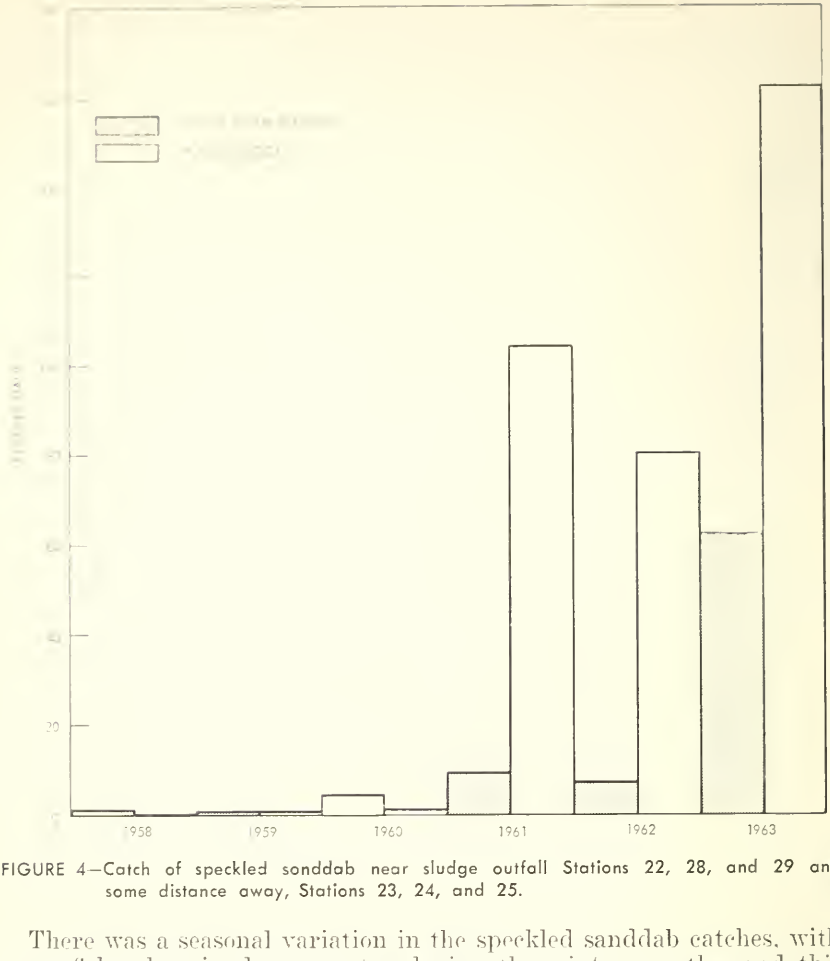

FIGURE 4—Catch of speckled sanddab near sludge outfall Stations 22, 28, and 29 and some distance away, Stations 23, 24, and 25.

There was a seasonal variation in the speckled sanddab catches, with more fish taken in deeper water during the winter months, and this factor may tend to obscure any effects of waste discharges at outfall termini.

Yellowchin sculpin (Figure 6) were caught in fewer numbers than flatfish in 1958. They peaked in abundance in 1961, especially in the southern inshore area of the bay. The increase was noticeable, but not so dramatic, in the northern inshore area. Yellowchin sculpin catches in general followed the catch trend for the bay. This species also avoided the effluent area, Stations 16, 17, and 21, being taken in considerably greater abundance at Stations 13, 14, and 15 (Figure 7).

California tonguefish catches (Figure 8) were relatively high in 1958, very low in 1959, and showed a gradual steady increase through 1962, followed by a moderate decrease in 1963. The same avoidance of the effluent area, but to a lesser extent, is exhibited by this species, with greater numbers being caught at Stations 13, 14, and 15, away from the effluent outfall, than at the nearer Stations 16, 17, and 21 (Figure 9).

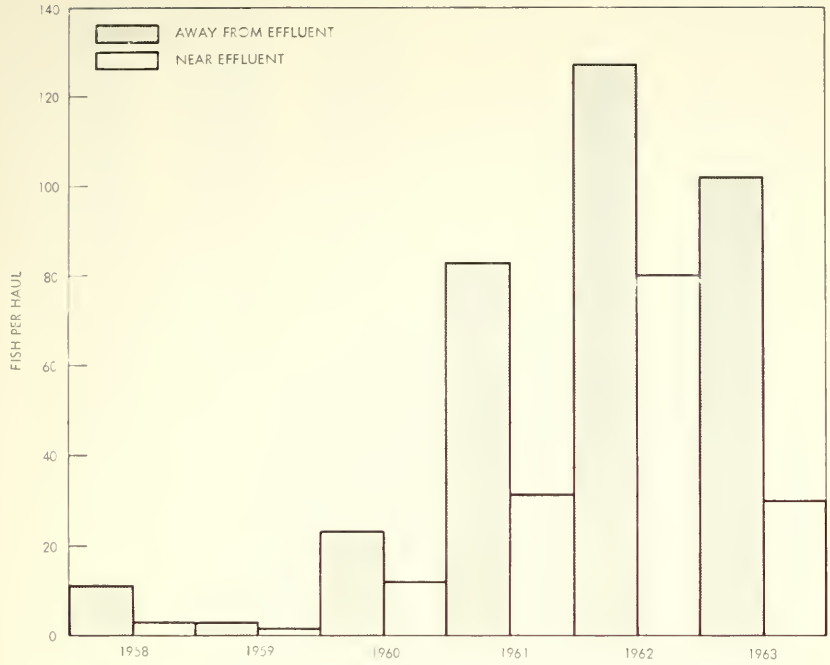

FIGURE 5—Catch of speckled sanddab near effluent outfall Stations 16, 17, and 21 and away from effluent outfall, Stations 13, 14, and 15.

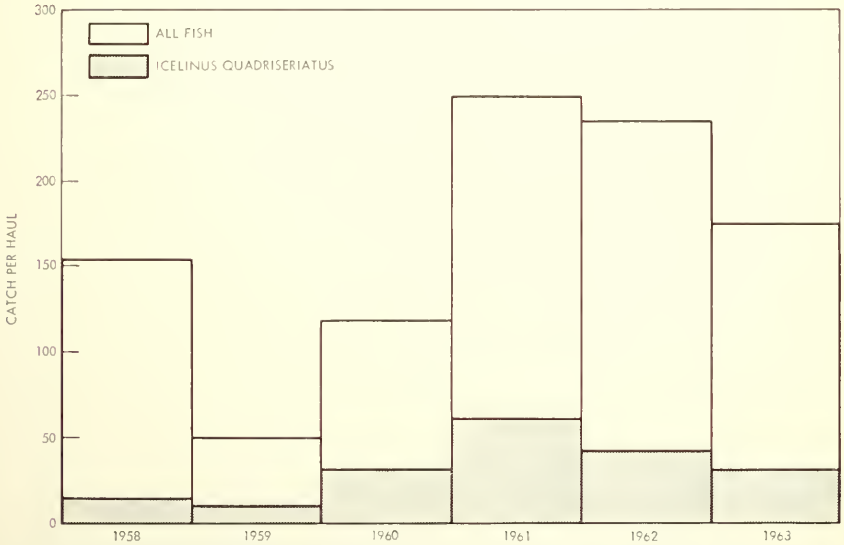

FIGURE 6—Catch per haul of yellowchin sculpin compared with that of all species.

FIGURE 7—Catch of yellowchin sculpin near effluent outfall Stations 16, 17, and 21 and away from effluent outfall, Stations 13, 14, and 15.

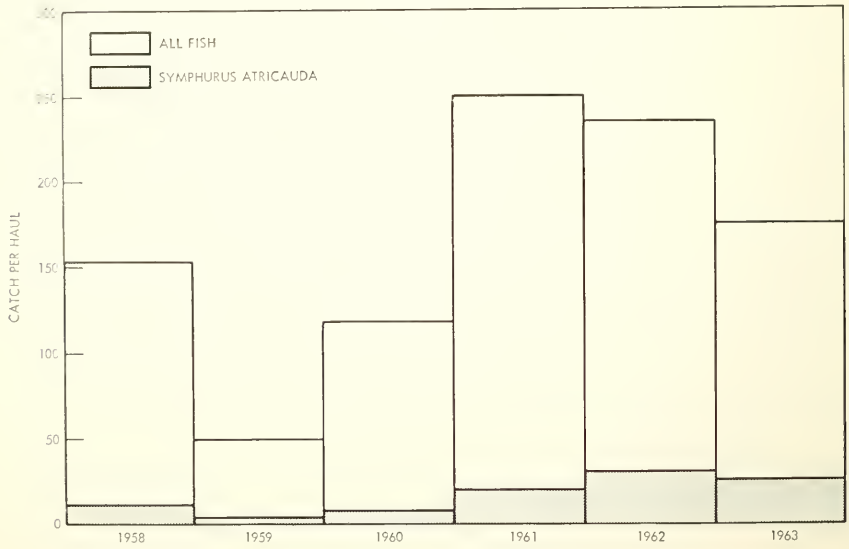

FIGURE 8—Catch per haul of California tonguefish compared with that of all species.

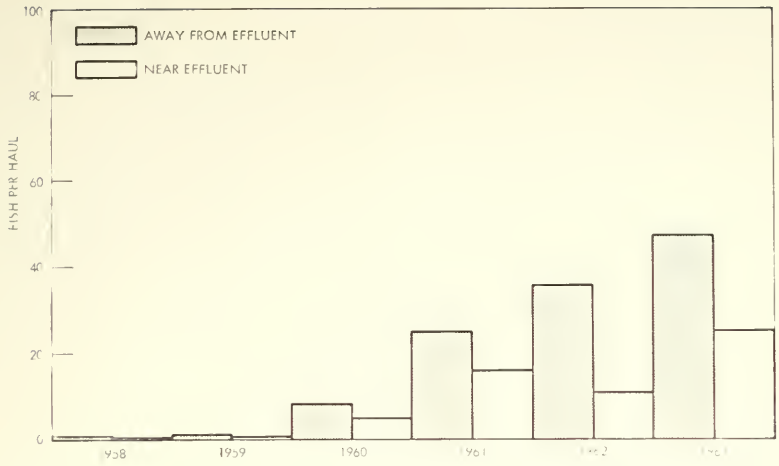

FIGURE 9—Catch per haul of California tanguefish near effluent outfall Stations 16, 17, and 21 and away from effluent outfall at Stations 13, 14, and 15.

The next species in order of abundance, the plainfin midshipman, followed a somewhat different pattern: a gradual increase in catch occurred from 1958 through 1961, without the usual 1959 decrease. A slight decrease occurred in 1962 and a greater decrease in 1963 (Figure 10).

Catches of slender sole increased gradually from 1958 through 1962 (Figure 11), with some dropoff in 1963. No special effect of the sludge or effluent on either the midshipman or the sole was noted.

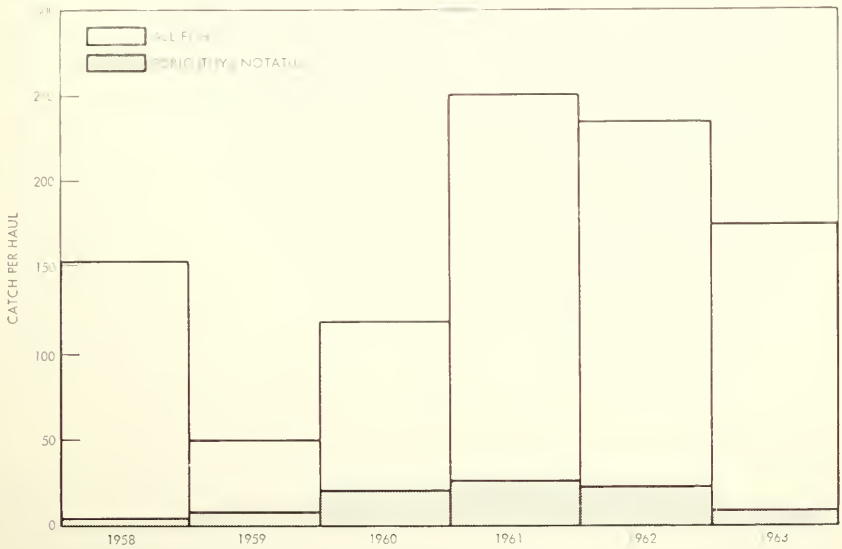

FIGURE 10—Catch per haul of plainfin midshipman compared with that of all species.

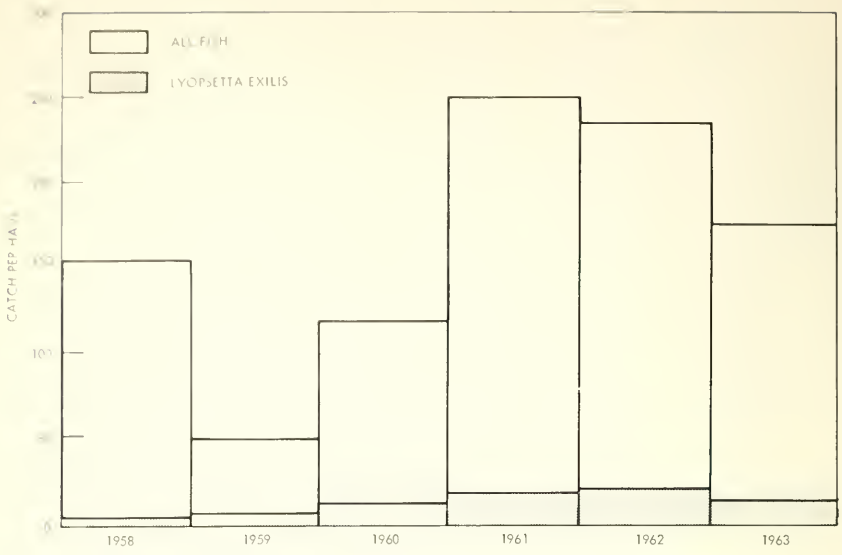

FIGURE 11—Catch per haul of slender sole compared with that of all species.

No valid reason for the fluctuations in the trawl catches is apparent, but it is evident from the data that some fishes tend to concentrate in enriched areas near sludge outfalls and others tend to avoid the effluent.

Other studies (Hartman, 1956) show that within a ½-mile radius of the end of the old 1-mile Hyperion outfall (discontinued in 1962, solid loadings removed in 1960) the faunal elements are limited both qualitatively and quantitatively and that the most abundant animals are polychaetes (*Nereis procera*, *Capitella capitata*, *Dioptra ornata*, and *Nothria elegans*). Mollusks, echinoderms, and crustaceans appear to be unusually low in abundance.

The difficulties in drawing conclusions about the effects of sewer effluent and sludge on bottomfish populations become more apparent when we realize the problems encountered in studies of the more stable and sedentary benthic fauna. The report by the Allan Hancock Foundation of the University of Southern California on studies conducted for the California State Water Quality Control Board (1965) states, "In an attempt to discern any net average effect of outfalls on the standing crop of benthic fauna, biomass results were averaged for stations within five miles of Los Angeles City and Los Angeles County outfalls, and within two miles of the Orange County Outfall. The average was 216 grams/sq. m., a result not differing significantly from the average for the study area," which was the entire southern California mainland shelf. One exception was *Listriolobus*, an echiuroid worm, a common species only on the Santa Barbara shelf.

In an attempt to find indicator species, the same investigators reached the conclusion "the presence of a single species does not adequately indicate any one set of conditions and hence cannot be safely used as an indicator of excessive amounts of waste discharge. One illustration is the abundance of a *Capitella* species which alone exists in peak numbers and reproducing populations directly under the ends of the

outfall lines. The same species has been found in similar abundance unaccompanied by other species, in areas far removed from shore and waste or polluted areas." The Hancock investigators also found that large and abundant parchment worm, *Chaetopterus*, populations occur in the area of White Point (where a great deal more solid organic material has been deposited than at Hyperion) and similar populations are found in unpolluted areas, including East End at Santa Catalina Island and Becher's Cove, Santa Rosa Island.

An examination of the surface and bottom temperature data taken during trawling operations revealed no correlation between the mean annual temperatures (Figure 12) and the fluctuations in trawl catches.

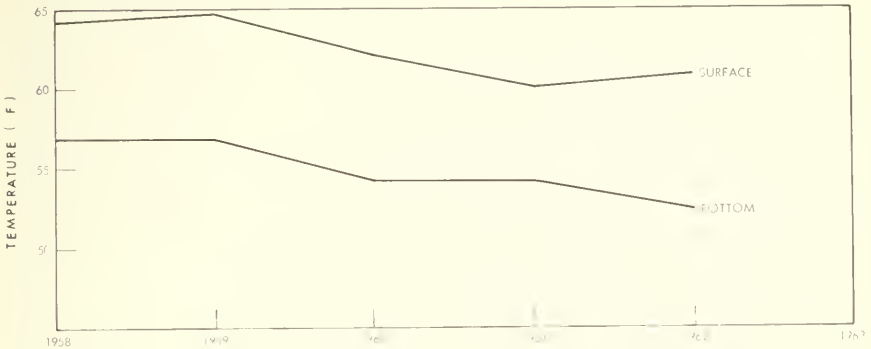

FIGURE 12—Santa Monica Bay mean annual surface and bottom temperatures for 1958 to 1963.

It is impossible to show that fluctuations in overall abundance, as measured by trawl catches, are the result of waste discharges in the study area, and are not due to natural causes. Nevertheless, our data do indicate that some species tend to avoid the immediate effluent discharge area and other species appear to be attracted to the sludge area. This attraction or repulsion to sludge and effluent causes local changes, but does not show Santa Monica Bay to be changing to an area untenable to fish life, as was once thought to be true.

EFFECT OF WASTE DISCHARGE ON SPORT CATCH

When the sport catch for the years 1958 through 1963 for Santa Monica Bay is scrutinized (Figure 13), no effect of waste discharge on the catch per angler day is evident. The large fluctuations evident in the yearly comparisons of trawl catches are missing in the sport-catch data. Small fluctuations in catch per angler day occurred from year to year, but no trend is apparent.

EFFECT OF POLLUTANTS ON ALGAL GROWTH

Although the direct effects of pollutants on large marine fish populations are difficult to measure, the effects of particulate matter deposited on the rocky nearshore environment appear all too obvious (North, 1964). Rocky areas and reefs, whether natural or artificial, may be subject to a buildup of particulate matter which smothers the gametes or other microscopic products of plant reproduction to the

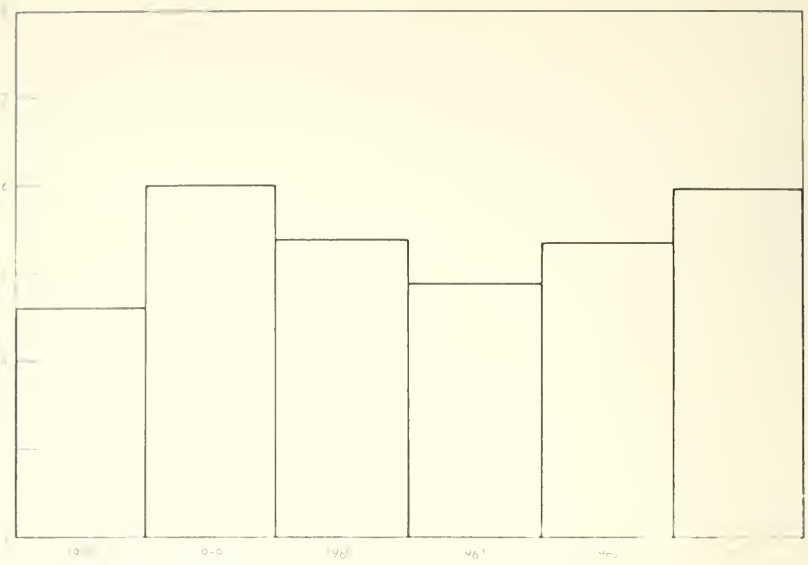

FIGURE 13—Party-boat catch per angler day for Santa Monica Bay.

extent that growth is almost completely inhibited. Turbidity of the water within the influence of large waste discharges may also cause serious problems of a major nature, and other constituents of the effluent may compound the problem.

Twenty old car bodies were placed off Paradise Cove during May 1958 in an area of normally healthy and plentiful giant kelp, *Macrocystis*, growth. By October 1958, giant kelp had established itself, by natural seeding, on the car body reef. Within 1 year a luxuriant kelp bed developed, undergoing the normal fluctuations between scarcity during warmwater periods (above 66 F) and heavy reproduction and growth when water temperatures fell below 66 F (Figure 14).

The kelp on the artificial reef remained plentiful from the time of the reef's placement until 1961, when the car bodies had deteriorated to a point where kelp holdfasts could no longer find attachment. The fish population reached a high of about 24,000 semiresidents but averaged approximately 11,000. Paradise Cove does not appear to be influenced by the effluent from the Hyperion Treatment Plant.

A streetcar reef (Figure 15) established in September 1958 off the Redondo-Palos Verdes coast, about 22 nautical miles south of the Paradise Cove reef, supported a peak population of only about 3,000 semiresident fish, with an average somewhat less than that. The lack of kelp could easily explain the difference. In this area, where deposition of particulate matter was related to sewage discharges, kelps of various species tried but invariably failed to gain a foothold (Carlisle, Turner, and Ebert, 1964). Kelp and sand bass supported a good sport fishery until the reef finally became reduced to rubble by late September 1961; afterward, the rubble continued to support a good population of sand bass for a period of about 4½ years. The fish population undoubtedly would have been much larger had kelp been able to develop.

Kelp also failed to gain a foothold on experimental artificial reefs composed of streetcars, car bodies, concrete shelters, and quarry rock or on large quarry rock reefs placed later (1960) off Malibu, Santa Monica, Hermosa Beach, and Redondo Beach. Waters off Palos Verdes Peninsula are now practically devoid of the kelp that was once so abundant.

FIGURE 14—Car body artificial reef off Paradise Cove, with its luxuriant growth of giant kelp. *Photograph by Charles H. Turner.*

That this particulate matter originates either at the Hyperion outfall, 8½ miles north of the streetcar reef, or the Los Angeles County White Point outfall, 9½ miles south, or at both, is obvious because the coastal surface current in Santa Monica Bay flows in a southerly direction about 85% of the time and northerly about 15% of the time (Paul Horrer, Marine Advisers, pers. comm.). This northerly reversal is in effect about 25 to 30% of the time along the Palos Verdes Peninsula (Wayne Messick, Los Angeles County Sanitation District, pers. comm.), and this current pattern would bring particulate matter and other outfall constituents into the area of the streetcar reef.

Considerably more research is needed to determine the effects of waste discharges on the nearshore rocky environment and the associated sessile organisms. A continuing definitive study of the effects on giant kelp in particular would fill a real need.

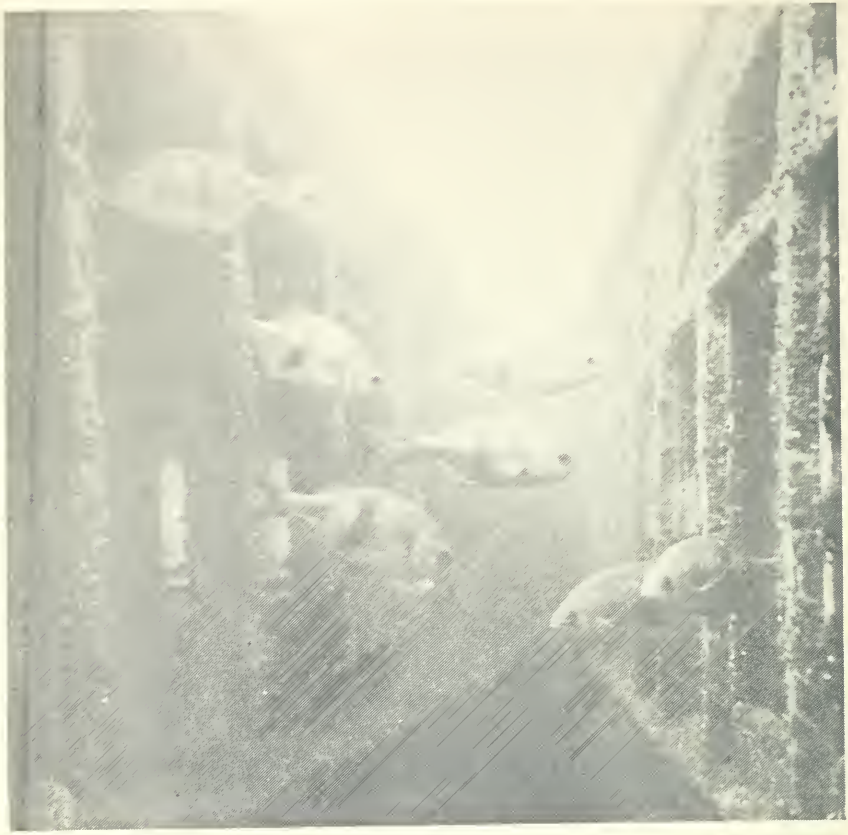

FIGURE 15—Streetcar artificial reef off Redondo Beach, showing total lack of giant kelp. *Photograph by Charles H. Turner.*

SUMMARY AND CONCLUSIONS

During the 6-year period 1958 through 1963, a trawl study was conducted in an attempt to assess the effects of large-scale waste discharge in Santa Monica Bay.

A total of 112,799 fish of 104 species was taken in the 705 trawls made in water varying in depth from 60 to 600 ft.

Five species, speckled sanddab, yellowchin sculpin, California tonguefish, plainfin midshipman, and slender sole, contributed more than 83,000 individuals to the total catch, and the evaluation is based mainly on these predominant species.

A general pattern of abundance was evident when the catch per haul was analyzed on an annual basis. There was a moderately high yield

in 1958, an extreme low in 1959, a buildup in 1960, a high in 1961, and a moderate drop in 1962 and 1963.

Speckled sanddab showed an attraction to the nutrient enriched area near the sludge outfall, while some species tended to avoid the immediate effluent discharge area.

It was impossible to show that fluctuations in abundance, as measured by trawl catches, were the result of large-scale waste discharge in the study area, and not due to natural causes.

The sport catch for the years 1958 through 1963 in Santa Monica Bay also failed to indicate anything more than small natural fluctuations.

Artificial reefs in Santa Monica Bay offered evidence that giant kelp was unable to survive in areas affected by the "fallout" of particulate matter or other constituents from waste discharges. An artificial reef outside the major influence of the discharge developed a luxuriant kelp bed.

ACKNOWLEDGMENTS

This research was begun and supervised for 5 years by John L. Baxter before I took over the project. The work accomplished during those 5 years and subsequent help on many occasions are gratefully acknowledged. John E. Fitch was extremely helpful throughout the entire project, giving generously of his time in the arduous task of fish sorting, in identification of fishes and invertebrates, and in many other ways.

This was a truly cooperative project and sincere thanks are due to many, especially in the carrying out of the field work. The following, in particular, must be included: Gordon Chapman, William Craig, William Donnelly, Ronald Little, Dennis Peterson, and Donald Zumwalt. Parke Young supplied useful data on the sport catch.

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Many thanks are also due those who helped in the task of invertebrate identification, particularly: S. Stillman Berry, James McLean, John Garth, Fred Ziesenhenne, and Olga Hartman.

Without all this help the project would have been truly impossible. One of the pleasures inherent in the completion of a research project is the opportunity to express gratitude to all those who made it possible.

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APPENDIX

FISHES TAKEN BY TRAWL

The biological notes which follow were collected in the course of the study and are abstracted here because very little biological information about many of the species is available.

Heterodontidae—horn sharks

Heterodontus francisci—horn shark
Size range 155–172 mm*
Depth 60 ft.

Scyliorhinidae—catsharks

Cephaloscyllium ventriosum—swell shark
Size 161 mm.
Depth 192 ft.

Triakidae—smoothhounds

Mustelus californicus—grey smoothhound
Size 231 mm.
Depth 60 ft.

Squalidae—dogfishes

Squalus acanthias—spiny dogfish
Size range 610–911 mm.
Depth range 60–120 ft.

Squatinidae—angel sharks

Squatina californica—Pacific angel shark
Stomach contents: *Sebastodes* sp.
Size range 1065–2200 mm.
Male 1065 mm SL, $22\frac{1}{4}$ lb.
Depth range 120–312 ft.

Platyrhinidae—thornbacks

Platyrhinoidis triseriata—thornback
Stomach contents: *Citharichthys stigmaeus*, *Crago* sp.
Size range 314–513 mm.
Male 525 mm, 769 g
Depth range 60–120 ft.

Rhinobatidae—guitarfish

Rhinobatos productus—shovelnose guitarfish
Size range 310–526 mm.
Depth 60 ft.

Rajidae—skates

Raja inornata—California skate
Size 226 mm.
Depth 570 ft.
Raja kincaidi—sandpaper skate
Size range 506–511 mm.
Male 544 mm., 865 g
Depth range 372–510 ft.

Torpedinidae—electric rays

Torpedo californica—Pacific electric ray
Stomach contents: *Genyonemus lineatus*
Sex 3♀, 7♂
Size range 156–830 mm.
Female 830 mm., 17.4 lb.
Depth range 60–460 ft.

Chimaeridae—chimaeras

Hydrolagus colliei—ratfish
Size range 122–444 mm.
Depth range 285–600 ft.

Argentinidae—argentines

Argentina sialis—Pacific argentine
Size range 51–178 mm.
Depth range 120–420 ft.

Synodontidae—lizardfishes

Synodus lucioceps—California lizardfish
Stomach contents: *Citharichthys stigmaeus*, *Engraulis mordax*, and *Loligo* sp.
Size range 68–280 mm.
Depth range 60–174 ft.

Merlucciidae—hakes

Merluccius productus—Pacific hake
Stomach contents: Euphausiids.
Size range 65–477 mm.
Depth range 360–600 ft.

Bothidae—lefteyed flounders

Citharichthys sordidus—Pacific sanddab
Stomach contents: Polychaetes, amphipods, euphasiids, fish, brittle stars.
Gonads: Spent in May.
Sex 12♀ 13♂
Size range 30–275 mm.
Depth range 60–528 ft.
Often with crustacean eye parasites.
Citharichthys stigmaeus—speckled sanddab
Stomach contents: Polychaetes, amphipods.
Gonads: Ripening and spent in May.
Sex 19♀ 7♂
Size range 29–132 mm.
Depth range 60–540 ft.
Citharichthys xanthostigma—longfin sanddab
Size range 79–170 mm.
Depth range 60–510 ft.
Eopsetta jordani—petrale sole
Gonads: Ripe in November.
Size range 145–461 mm.
Female 347 mm. SL, 770 g
Depth range 60–360 ft.
Glyptocephalus zachirus—rex sole
Size range 65–372 mm.
Female 286 mm. SL, 241 g
Depth range 300–600 ft.
Hippoglossina stomata—bigmouth sole
Stomach contents: Stomatopods.
Gonads: Transparent eggs in October and November.
Female 229 mm. SL, 175 g
Size range 35–318 mm.
Depth range 60–436 ft.
Hypsopsetta guttulata—diamond turbot
Size range Not recorded.
Depth 60 ft.
Parolichthys californicus—California halibut
Stomach contents: *Engraulis mordax*.
Gonads: Running ripe in January.
Sex 10♀ 33♂
Male 480 mm. SL, 2024 g
Size range 135–661 mm.
Depth range 60–436 ft.

* Total length is used for size ranges, unless otherwise noted.

APPENDIX—Continued

FISHES TAKEN BY TRAWL

Pleuronichthys ritteri—spotted turbot
Gonads: Running ripe in November.
Size range ..... 178–240 mm.
Depth range ..... 60–285 ft.

Pleuronichthys verticalis—hornyhead turbot
Stomach contents: Polychaetes.
Gonads: Ripe and spawning in May, July, and August; spent in September and October.
Sex ..... 21 ♀ 2 ♂
Size range ..... 30–300 mm.
Female ..... 200 mm. sl., 200 g
Depth range ..... 60–414 ft.

Xystreurys liolepis—fantail sole
Stomach contents: Stomatopods.
Gonads: Running ripe in November.
Sex ..... 16 ♀ 29 ♂
Size range ..... 37–285 mm.
Female ..... 321 mm. sl., 542 g
Depth range ..... 60–348 ft.

Cynoglossidae—tonguefishes

Symphurus atricauda—California tonguefish
Gonads: Ripe and spent July, August, and September.
Size range ..... 36–199 mm.
Depth range ..... 60–563 ft.

Fleuronectidae—righteyed flounders

Lyopsetta exilis—slender sole
Stomach contents: Shrimp.
Gonads: Ripe in October and December.
Sex ..... 12 ♀ 2 ♂
Size range ..... 28–249 mm.
Depth range ..... 60–600 ft.

Microstomus pacificus—Dover sole
Size range ..... 43–337 mm.
Male ..... 246 mm. sl., 225 g
Depth range ..... 60–600 ft.
Parasites, growths, and fin rot frequent.

Parophrys vetulus—English sole
Stomach contents: Brittle stars, polychaetes, clam siphons.
Gonads: Ripe in February, April, and June; spawning in December; spent in June.
Sex ..... 105 ♀ 63 ♂
Size range ..... 44–408 mm
Female ..... 307 mm. sl., 475 g
Depth range ..... 60–600 ft.

Pleuronichthys coenosus—C-O turbot
Gonads: Running eggs in July; ripe and spent in September, October, November, and December.
Size range ..... 91–333 mm.
Male ..... 250 mm. sl., 390 g
Depth range ..... 60–192 ft.

Pleuronichthys decurrens—curlfin turbot
Stomach contents: Brittle stars.
Gonads: Transparent eggs and spent in October, November, and January.
Male ..... 191 mm. sl., 243 g
Size range ..... 66–274 mm.
Depth range ..... 60–348 ft.

Serranidae—basses

Paralabrax clathratus—kelp bass
Size range ..... 19–79 mm.
Depth range ..... 60–120 ft.

Paralabrax nebulifer—sand bass
Stomach contents: Fish.
Gonads: Ripening in August.
Size range ..... 212–332 mm.
Depth ..... 60 ft.

Stromateidae—butterfishes

Palometa simillima—Pacific pompano
Size range ..... 90–155 mm.
Depth range ..... 60–180 ft.

Sciaenidae—croakers

Genyonemus lineatus—white croaker
Stomach contents: Fish, *Crago*, worms.
Gonads: Ripening in November, December, and January.
Sex ..... 12 ♀ 9 ♂
Female ..... 248 mm. sl., 357 g
Size range ..... 28–305 mm.
Depth range ..... 60–426 ft.
Parasites and growths frequent.

Seriphus politus—queenfish
Size range ..... 55–272 mm.
Depth range ..... 60–126 ft.

Embiotocidae—surfperches

Cymatogaster aggregata—shiner perch
Size range ..... 45–211 mm.
Depth range ..... 60–346 ft.

Embiotoca jacksoni—black perch
Size range ..... 86–273 mm.
Depth ..... 60 ft.

Hyperprosopon argenteum—walleye surfperch
Size range ..... 119–180 mm.
Depth ..... 60 ft.

Hypsurus caryi—rainbow seaperch
Size ..... 190 mm.
Depth ..... 60 ft.

Phanerodon furcatus—white seaperch
Size range ..... 60–226 mm.
Depth range ..... 60–126 ft.

Rhacochilus toxotes—rubberlip perch
Size range ..... 128–285 mm.
Male ..... 198 mm. sl., 242 g
Depth ..... 60 ft.

Rhacochilus vacca—pile perch
Size range ..... 93–264 mm.
Male ..... 190 mm. sl., 212 g
Depth range ..... 60–226 ft.

Zalembius rosaceus—pink seaperch
Size range ..... 43–186 mm.
Depth range ..... 60–600 ft.

APPENDIX—Continued

FISHES TAKEN BY TRAWL

Scorpaenidae—rockfishes

Scorpaena guttata—sculpin
Stomach contents: Octopi.
Size range—63–370 mm.
Female—299 mm. SL, 1092 g
Depth range—60–288 ft.

Sebastodes alutus—Pacific ocean perch
Size—138 mm.
Depth—354 ft.

Sebastodes auriculatus—brown rockfish
Size range—130–310 mm.
Depth range—60–180 ft.

Sebastodes chlorostictus—greenspotted rockfish
Size range—36–463 mm.
Male—358 mm. SL, 1350 g
Depth range—177–600 ft.

Sebastodes constellatus—starry rockfish
Size range—81–340 mm.
Depth range—186–414 ft.

Sebastodes crameri—dark-blotched rockfish
Size range—80–86 mm.
Depth range—180–423 ft.
First record south of Point Conception.

Sebastodes dalli—calico rockfish
Stomach contents: Fish, amphipods, octopi, and euphausiids.
Gonads: Ripe in November, December, January, April, and May; spent in May.
Sex—72 ♀ 23 ♂
Size range—80–180 mm.
Depth range—60–120 ft.

Sebastodes diploproa—splitnose rockfish
Size range—13–420 mm.
Depth range—180–600 ft.

Sebastodes elongatus—greenstriped rockfish
Size range—61–272 mm.
Depth range—180–519 ft.

Sebastodes goodei—chilipepper
Size range—132–337 mm.
Depth—216 ft.

Sebastodes jordani—shortbelly rockfish
Size range—80–227 mm.
Depth range—378–600 ft.

Sebastodes levis—cow rockfish
Stomach contents: Squid.
Size range—73–184 mm.
Depth range—180–600 ft.

Sebastodes macdonaldi—Mexican rockfish
Size range—91–117 mm.
Depth range—180–552 ft.

Sebastodes miniatus—vermilion rockfish
Size range—35–265 mm.
Depth range—60–216 ft.
Fins often parasitized by copepods.

Sebastodes paucispinis—bocaccio
Size range—149–314 mm.
Depth—120 ft.

Sebastodes rubrivinctus—flag rockfish
Size range—71–333 mm.
Depth range—192–378 ft.

Sebastodes saricola—stripetail rockfish
Gonads: Running ripe in October.
Size range—30–236 mm.
Depth range—60–600 ft.

Sebastodes semicinctus—halfbanded rockfish
Gonads: Ripening October and November; ripe in February; running ripe in April; spent in May.
Sex—20 ♀ 2 ♂
Size range—55–182 mm.
Depth range—180–420 ft.

Sebastodes serranoides—olive rockfish
Size range—168–190 mm.
Depth—60 ft.

Sebastodes umbrosus—honeycomb rockfish
Size—121 mm.
Depth—185 ft.

Sebastodes vexillaris—whitebelly rockfish
Size—365 mm.
Depth—Not recorded.

Sebastodes zacentrus—sharpchin rockfish
Size—174 mm.
Depth—300 ft.

Sebastolobus alascanus—shortspine channel rockfish
Size range—75–182 mm.
Depth—588 ft.

Sebastolobus altivelis—longspine channel rockfish
Size—168 mm.
Depth—600 ft.

Anoplopomatidae—sablefishes

Anoplopoma fimbria—sablefish
Size range—27–329 mm.
Depth range—339–436 ft.

Hexagrammidae—greenlings

Oxylebius pictus—painted greenling
Size range—65–70 mm.
Depth range—60–186 ft.

Zaniolepidae—combfishes

Zaniolepis frenata—shortspine combfish
Stomach contents: Polychaetes, euphausiids, shrimp, worms, amphipods, eggs.
Gonads: Ripe in September and December.
Sex—11 ♀ 10 ♂
Size range—75–224 mm.
Depth range—180–600 ft.

Zaniolepis latipinnis—longspine combfish
Stomach contents: Polychaetes, eggs.
Gonads: Ripe in April, May, November, December, and January.
Size range—57–187 mm.
Depth range—118–348 ft.

Cottidae—sculpins

Artedius notospilotus—bonehead sculpin
Stomach contents: *Pyromaia*.
Size range—60–184 mm.
Depth—60 ft.

Chitonotus pugetensis—roughback sculpin
Stomach contents: Shrimp.
Size range—100–132 mm.
Depth range—126–186 ft.

Icelinus filamentosus—threadfin sculpin
Size—251 mm.
Depth range—Not recorded.

Icelinus fimbriatus—fringed sculpin
Stomach contents—*Crago*, *Cancer*.
Size range—155–199 mm.
Depth range—192–279 ft.

APPENDIX—Continued

FISHES TAKEN BY TRAWL

[illegible] sculpin
Stomach contents: Shrimp, eggs.
Gonads: Ripening in April; ripe and spent in May.
Sex ..... 18♂ 17♀
Size range ..... 23–91 mm.
Depth range ..... 60–108 ft.

[illegible] spatulus—spatulate sculpin
Stomach contents: *Copepoda*, polychaetes, bivalve, crab spores
Gonads: Ripe in April.
Size range ..... 55–121 mm.
Depth range ..... 186–600 ft.

[illegible] tenuis—slender sculpin
Size range ..... 56–135 mm.
Depth range ..... 180–490 ft.

[illegible]—cabezon
Size ..... 70 mm.
Depth ..... 60 ft.

Rhamphocottidae—grunt-sculpins

Rhamphocottus [illegible]—grunt-sculpin
First record for southern California.
Size range ..... 69–70 mm.
Depth range ..... Not recorded.

Agonidae—poachers

[illegible]—northern spearnose poacher
Size range ..... 128–193 mm.
Depth ..... 288 ft.

Agonopsis sterletus—southern spearnose poacher
Size range ..... 84–141 mm.
Depth range ..... 60–222 ft.

Odontopyxis trispinosa—pygmy poacher
Gonads: Ripe and spent in April.
Size range ..... 37–101 mm.
Depth range ..... 60–300 ft.

Xeneretmus latifrons—blacktip poacher
Stomach contents: Polychaetes.
Gonads: Ripe in November; transparent eggs in December.
Size range ..... 41–160 mm.
Depth range ..... 60–600 ft.

Xeneretmus triacanthus—bluespotted poacher
Stomach contents: Amphipods, polychaetes.
Gonads: Ripe in April.
Size range ..... 61–175 mm.
Depth range ..... 174–480 ft.

Uranoscopidae—stargazers

Kathetostoma averruncus—smooth stargazer
First and third specimens for California, taken by *Pyxidis*.
Size range ..... 183–260 mm.
Depth range ..... 260–315 ft.

Syngnathidae—pipefishes

Syngnathus spp.—pipefishes
Gonads: Eggs in August; females spent in September; males carrying young in September and December.
Sex ..... 1♀ 10♂
Size range ..... 125–272 mm.
Depth range ..... 60–126 ft.

Gobiidae—gobies

Coryphopterus nicholsi—bluespot goby
Gonads: Ripening in October.
Size range ..... 70–117 mm.
Depth range ..... 60–348 ft.

Lepidogobius lepidus—bay goby
Gonads: Ripening in May.
Size range ..... 30–103 mm.
Depth range ..... 60–300 ft.

Batrachoididae—toadfishes

Porichthys myriaster—specklefin midshipman
Size range ..... 50–433 mm.
Depth range ..... 60–387 ft.

Porichthys notatus—plainfin midshipman
Stomach contents: Fish.
Gonads: Immature in August; ripe in May, June, July, and December.
Size range ..... 25–296 mm.
Depth range ..... 60–600 ft.

Clinidae—klipfishes

Heterostichus rostratus—giant kelpfish
Size ..... 106 mm.

Neoclinus blanchardi—sarcastic fringehead
Stomach contents: *Pyromaia* sp., shrimp.
Gonads: Ripe in July.
Size range ..... 83–218 mm.
Depth range ..... 60–240 ft.

Stichaeidae—pricklebacks

Plectobranchus evides—bluebarred prickleback
Size range ..... 84–93 mm.
Depth ..... 400 ft.

Poroclinus rothrocki—whitebarred blenny
Size range ..... 95–97 mm.
Depth range ..... 414–600 ft.

Bathymasteridae—ronquils

Rathbunella hypoplectus—smooth ronquil
Stomach contents: Polychaetes.
Gonads: Transparent eggs in August; ripe in January.
Size range ..... 27–217 mm.
Depth range ..... 120–288 ft.

Zoarcidae—eelpouts

Aprodon cortezianus—smoothgum eelpout
Size ..... 166 mm.
Depth ..... 588 ft.

Lycodopsis pacifica—blackbelly eelpout
Gonads: Ripe in October and December.
Size range ..... 64–355 mm.
Depth range ..... 180–600 ft.

Lyconema barbatum—bearded eelpout
Size range ..... 81–126 mm.
Depth ..... 425 ft.

Brotulidae—brotulas

Brosmophycis marginata—red brotula
Size range ..... not recorded
Depth ..... 378 ft.

Ophidiidae—cusk-eels

Otophidium scrippsi—basketweave cusk-eel
Size range ..... 85–247 mm.
Depth range ..... 60–198 ft.

Otophidium taylori—spotted cusk-eel
Size range ..... 132–295 mm.
Depth range ..... 60–570 ft.

Calif. Fish and Game, 55(1) : 47–52. 1969.

A SURVEY OF ALGAE OFF PALOS VERDES POINT, CALIFORNIA[1]

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A survey, utilizing scuba, was made in March, April, and May, 1966, off Palos Verdes, California, to determine algal abundance and to collect specimens. This survey was conducted on a rocky substrate at preselected depths of 20, 40, 60 and 80 ft. At depths beyond 80 ft the rocky substrate was replaced by sand. Although beds of giant kelp, *Macrocystis pyrifera*, were once present in the area, none is currently found there. Many algal investigations off the California coast have been confined to the flora associated with kelp beds; this survey was unique because it was concerned with algae growing on a rocky substrate in an area devoid of giant kelp.

Twenty genera of algae were noted. Reds (Rhodophyta) were the most numerous, comprising 75% of the genera collected. Only 5 genera of browns (Phaeophyta) were found, all at the 20- and 40-ft depths. No green algae (Chlorophyta) were recorded.

INTRODUCTION

Investigations of algae utilizing scuba have increased in recent years. Previously, sublittoral algae were identified from specimens washed ashore, or caught with biological dredges, gill nets, and other fishing gear, and from collections made by hard-hat divers. We conducted a literature search and found no published reports of a survey along the California coast primarily concerned with the algae present on a rock substrate devoid of *Macrocystis*. Most underwater investigations employing scuba have been concerned primarily with the fauna, and have given only cursory treatment to the flora. One exception is the work of Dawson, Neushal, and Wildman, 1960 (Table 1).

The purpose of our study was to survey the species and abundance of algae present at selected depths on a rocky shelf off Palos Verdes Point, California. During the spring of 1966, we used scuba to visually estimate the algal abundance at these selected depths.

AREA DESCRIPTION

The study area lies off Palos Verdes Point, Los Angeles County, California (Figure 1). The shoreline is a narrow rocky beach backed by steep shale cliffs.

Rocky shelves extend from the shore to depths of approximately 80 ft. Inshore, sand areas are interspaced among the rock shelves. Large boulders are scattered throughout the area; these decrease in size and

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TABLE 1

Algae Recorded During Subtidal Ecological Surveys, Employing Scuba Diving Techniques

Investigation	Genera	Species	Remarks
Limbaugh, 1955	17	18	An investigation of the fish life in the kelp beds and the effects of kelp harvesting from Monterey, California, to San Benito Islands, Baja California
Abbott, 1956	19	21	A quantitative study of the benthic communities inhabiting the kelp beds off La Jolla, California
Dawson, Neushul, and Wildman, 1960	79	111	The floristic composition of seaweeds associated with kelp beds from Point Conception, California, to Alijos Rocks, Baja California
McLean, 1962	38	41	The sublittoral ecology of kelp beds of the open coast area near Carmel, California
Pequegnat, 1964	7	7	The epifauna of a siltstone reef devoid of *Macrocystis* off Corona del Mar, California
Turner, Ebert, and Given, 1964	11	11	An ecological survey of a kelp bed and a sandy environment in the vicinity of Canyon de las Encinas, San Diego, California
Turner, Ebert, and Given, 1965	21	23	An ecological survey of a kelp bed and a sandy environment off San Elijo Lagoon, San Diego, California
Turner, Ebert, and Given, 1966	41	52	An ecological survey in a kelp bed off Point Loma, San Diego
Strachan and Koski, 1968 (this survey)	19	20	A survey of algae on a rocky substrate devoid of kelp beds off Palos Verdes Point, California

number with depth. Beyond the 80-ft depths, sand becomes the dominant substrate.

While beds of *Macrocystis* are not currently found in this area, historically lush beds were present. "In former times kelp beds extended almost continuously around the Palos Verdes peninsula from Redondo Beach to Cabrillo Beach" (North, 1967).

MATERIALS AND METHODS

Observations and collections were made at depths of 20, 40, 60, and 80 ft along a transect extending 230° magnetic from Palos Verdes Point toward a red navigational buoy anchored 0.75 mile offshore. Diving was conducted from the Department's 20-ft cabin cruiser *Dolphin* equipped with a Raytheon DE-705A recording fathometer which enabled us to locate the survey stations along the transect. At each station the boat was anchored. A 2.2-m line was attached to the anchor and samples were collected within a 15-m^2 circle, using this line as the radius. Representative algae were removed from rocks and placed in plastic jars or net sacks for laboratory identification. Observations, recorded underwater on a plastic writing slate, were later transcribed into a permanent notebook. Bottom depth was measured with a divers' depth gauge, and surface and bottom temperatures were determined with a bucket thermometer.

RESULTS

Eleven dives requiring 280 min of bottom time were made. Collections and observations were made at each station on March 25 and April 15, 1966. On May 6, dives were limited to the 60- and 80-ft sta-

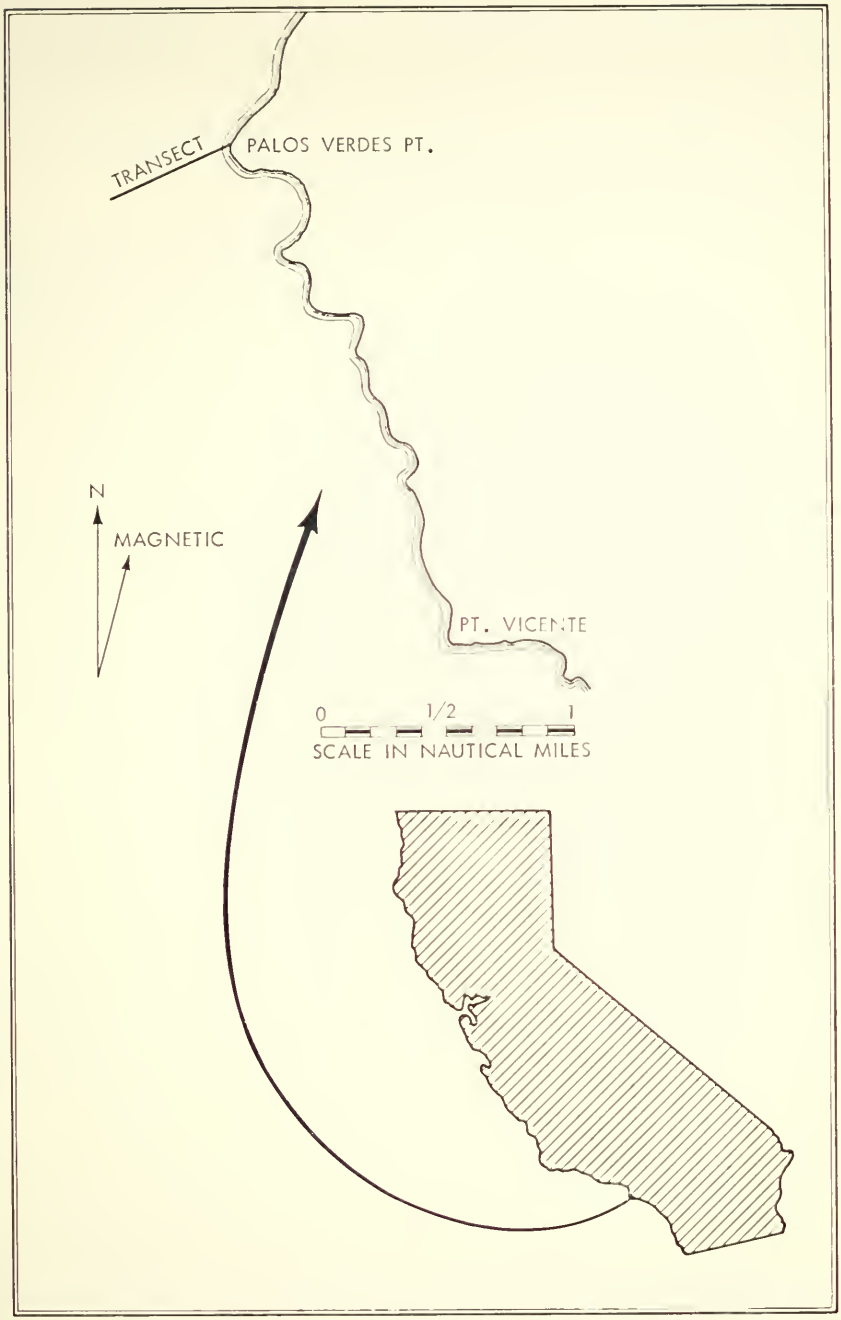

FIGURE 1—Location of study area off Palos Verdes Point, California.

dives because of adverse sea conditions. There were no noticeable differences in the flora on May 6, although we did note a marked change in bottom temperatures. A dive was made at the 20-ft station on May 17, 1966, to obtain samples of *Cystoseira* which, until then, we had not identified with certainty because the plants were in generally poor condition and the upper portions with float vesicles were missing. During this dive we observed sea hares, *Aplysia californica* and *A. vaccaria*, actively grazing on the upper parts of *Cystoseira*.

Water temperature and wave surge varied greatly with each dive (Table 2). Wave surge reached its greatest intensity at the 20-ft depth. Underwater visibility was estimated visually and varied from 20 to 30 ft.

TABLE 2

Diving Station Data

Date	Depth (ft)	Duration (min)	Underwater temperature (°F)	Surface temperature (°F)	Bottom temperature (°F)	Surge	Bottom description
Mar. 25 (1966)	20	40	50	55.2	55.4	Heavy	Rocky substrate with large boulders
Mar. 25 (1966)	40	40	50	55.2	50.7	Medium	Rocky shelf, some sand and small boulders
Mar. 25 (1966)	60	30	50	55.2	52.4	Light	Rocky substrate, some sand
Mar. 25 (1966)	80	20	50	54.7	52.1	None	Mostly sandy substrate
Apr. 15 (1966)	20	25	55	57.1	57.1	Heavy	Rocky substrate with large boulders
Apr. 15 (1966)	40	25	55	59.0	56.4	Light	Rocky substrate, some sand and boulders
Apr. 15 (1966)	60	20	50	55.8	53.1	Light	Rocky substrate, some sand
Apr. 15 (1966)	80	20	50	55.7	54.8	Light	Substrate half sand and half rock
May 6 (1966)	40	20	55	59.2	58.1	Medium	Rocky substrate, some sand and boulders
May 6 (1966)	80	20	55	59.2	57.0	Light	Mostly sandy substrate
May 17 (1966)	20	45	55	57.2	56.8	Medium	Rocky substrate, little sand and large boulders

We collected and identified 20 algal genera (Table 3). Fifteen of these were red algae (Rhodophyta) and 5 were brown algae (Phaeophyta). Green algae (Chlorophyta) were neither observed nor collected.

The greatest diversity of algae was observed at the 20-ft station: 12 reds and 4 genera of browns. At 40 ft, 12 genera of reds and 3 browns were recorded. The number of genera decreased with depth: at 60 ft, only 7 reds were noted, and only 3 genera of calcareous red algae (corallines) were found at the 80-ft station.

Of the 5 genera of brown algae, only *Cystoseira* and *Ilea* were common at both the 20- and 40-ft depths.

The fleshy red alga *Gelidium* was abundant at the 20-ft station. The low-growing reds *Phyllophora* and *Rhodymenia* were common at the 40- and 60-ft stations. *Polysiphonia* and the red alga *Callithamnion* or *Pleonosporium* were also present at the 40-ft depth. Positive identification of the latter 2 genera was uncertain, due to the lack of sporangia.

TABLE 3

Abundance of Algae Recorded Off Palos Verdes Point, California, 1966 [*]

	March				April			
	Depth (ft)				Depth (ft)			
	20	40	60	80	20	40	60	80
Phaeophyta								
Colpomenia sinuosa	s							
Cystoseira osmundacea	C	C			C	C		
Egregia laevigata		s				s		
Eisenia arborea	s				s			
Hesperophycus californicus		C			C	C		
Rhodophyta (fleshy)								
Callophyllis flabellulata	s	C				C		
Gastroclonium coulteri	C				C			
Gelidium purpurascens	A				A			
Gigartina spp.	s							
Laurencia pinnatifida						s		
Leptosiphonia californica					s			
Polyneura latissima	C	C	C			C	C	
Polysiphonia spp.		C	C			C	C	
Prionitis lanceolata	C					C		
Pterosiphonia sp.	C	C	C			C	C	
Rhodophyta (calcareous)								
Alaria marginata		C	C	s		C		s
Bossiella orbigniana	C	C				C		
Calliarthron tuberculosum	C		C		C		s	
Corallina officinalis vancouveriensis	C	C			s			
Lithothamnium and *Lithophyllum*	s	C	C	A	s	C	A	A

[*] Abundance is recorded as follows:

C = Common (the most frequently encountered species)

s = Sparse (those species which were found in small numbers)

A = Abundant (those species which were found in large numbers, sometimes dominant)

Coralline algae were present at each station and comprised 6 of the 20 genera collected. *Lithothamnium* or *Lithophyllum* or both were sparse at the 20-ft stations and were common at 40 ft. They incrusted all the rocks and boulders at 60 ft, and continued as the most abundant algae at 80 ft.

Algae not found, but typical of kelp beds and of those now present in this area, include: *Laminaria*, *Agarum*, *Pterygophora*, *Zonaria*, *Dictyopteris*, *Codium*, *Plocamium*, etc. (Dawson, 1966).

DISCUSSION AND CONCLUSIONS

Macrocystis pyrifera beds that were once prevalent in the area no longer exist (North, 1964). Presumably they succumbed to adverse environmental factors. Factors which singly or in combination may have contributed to their demise are: pollution, high water temperatures, and overgrazing by purple sea urchins, *Strongylocentrotus purpuratus*, and red sea urchins, *S. franciscanus*. Two of the six corallines we recorded, *Corallina* and *Calliarthron*, are apparently immune to the voracious sea urchins (Dawson, Neushul, and Wildman, 1960).

Our study area lies between two major sewage discharges, White Point and Hyperion, which discharge 650 million gal of treated sewage

daily. Tidal currents carry this sewage into the study area and it greatly affects the biota. "Historical charts reveal that in the Palos Verdes area, under the influence of the discharge from the Los Angeles County Sanitation District's outfall at White Point, disappearance of kelp beds started in the vicinity of the outfall and proceeded away from the discharge" (North, 1964). In our opinion, the giant kelp beds will not come back without controlling both the sewer outflow and the grazing animals.

ACKNOWLEDGMENTS

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Calif. Fish and Game, 55(1) : 53–68. 1969.

THE MARINE ENVIRONMENT IN THE VICINITY OF THE SAN GABRIEL RIVER MOUTH[1]

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During April and May 1966, California Department of Fish and Game biologist-divers conducted an ecological assessment of the benthic biota in the vicinity of the San Gabriel River mouth. This study, conducted for the State Water Quality Control Board (now State Water Resources Control Board), gathered data which will be used by the Board in evaluating the effect waste discharges and proposed waste discharges into the San Gabriel River will have on the nearshore area.

The 11 stations occupied included such habitats as sand bottom, river bottom, and the rock jetties bordering the general study area.

A lush and diversified biotic assemblage adhered to the jetty rocks (19 plants and 81 animals), while the sand stations were inhabited by smaller and less obvious organisms, yielding from 17 to 34 species per station, with an average of 28. Polychaetes were the dominant organisms found at all but one station. At one river bottom station, annelids, mollusks, and arthropods were found in approximately equal numbers, but there was a limited fauna in the samples at the other two river bottom stations, in part because of sampling difficulties.

In general, the area was "healthy" in 1966, and a wide variety of organisms was present. Conditions have improved greatly since 1952 and 1954, when similar studies were conducted, but the lack of fleshy brown algae on the jetty rocks indicates that conditions are not yet optimal.

INTRODUCTION

The California Department of Fish and Game and the State Water Quality Control Board[2] (through the Santa Ana River Basin Regional Water Quality Control Board) entered into an agreement February 15, 1966, whereby Department biologist-divers made an ecological investigation of the marine environment in the vicinity of the San Gabriel River mouth. The investigation was directed toward an assessment, by direct observation where possible, of the density and diversity of animal life and associated vegetation.

The data we gathered will be used by the Board in evaluating the effects of various waste discharges and proposed waste discharges on the beneficial uses (as prescribed in the Board's water quality control policy) of these nearshore waters.

AREA DESCRIPTION

The study area lies offshore from the City of Seal Beach (Figure 1). Here, the soft, gray, silty sand ocean floor slopes gently seaward, reaching a depth of 30 ft (the limit of this study) 1,900 yards offshore.

The shore, a broad sandy beach (up to 400 yards wide), is protected from prevailing westerly swells by the Los Angeles–Long Beach Harbor

[1] Accepted for publication September 1968.
[2] Now State Water Resources Control Board.

FIGURE 1—Location chart showing the trawling and survey stations.

Breakwater southwest of the study zone. The east and west boundaries of the study area were marked by the west jetty of Anaheim Bay and the east jetty of Alamitos Bay. These jetties, together with tide, wind, and currents, tend to retain the waters flowing from the San Gabriel River against the shore. At this point the San Gabriel River is merely a flood control channel; its primary water sources are freshwater runoff and seawater used as coolant for steam-electric stations upstream. A small jetty is located at the east side of the river mouth. Warm river waters swirling around this rock jetty and held against the shore by wind and tide have so modified the local environment that abnormally high numbers of round stingrays, *Urolophus halleri*, abound in the shallows (John Stanley Babel, Pasadena City College, pers. comm.). The increased water temperatures, presumably an attraction for these fish, are attributable to warm coolant waters discharged into the river some distance upstream.

METHODS

The field work was done during April and May 1966. On the first day, trawling was conducted along six tracks (Figure 1) with a modified Gulf of Mexico-style shrimp try net (10-ft opening, 20-ft length, 0.5-inch mesh) to sample fishes which might otherwise be missed during diving surveys. The trawling stations included nearshore (less than 10-ft depths), mid-distance (about 20-ft depths), and offshore areas (30-ft depths—the limit of our survey). For comparative purposes, a nearshore trawling station was occupied along Belmont Shore.

On subsequent days, diving surveys were made at 10-, 20-, and 30-ft depths along two ranges perpendicular to shore (approximately 200° magnetic). One range began near the eastern edge of the river mouth, the other approximately 300 yards east of the Seal Beach pier. Additional stations were occupied on the Alamitos and Anaheim Bay jetties

and at three points in the San Gabriel River: (i) at the river mouth, (ii) at the Marina Drive bridge, and (iii) at the Pacific Coast Highway bridge.

Sampling conducted and data obtained at each station included (with modifications as the situation dictated): (i) a vertical plankton tow, using a standard 18-cm diameter oblong plankton net with 62-μ mesh; (ii) a core sample, using a diver-held coring tube; (iii) water temperatures, at the bottom, and through the water column; (iv) water visibility estimates (horizontal) at the bottom and through the water column; (v) general bottom description; (vi) enumeration (by estimate) of the larger plants and animals, including fishes; (vii) sampling (by actual removal) of growths in rocky areas; (viii) sampling in the soft bottom areas with a small Hayward orange-peel grab; and (ix) substrate sampling for polychaetes. Methods of sampling and specimen identification follow those described by Turner, Ebert, and Given (1965; 1966), except that overall poor water visibility precluded our employing the arc technique to define the study areas. Instead, we swam lines tangent to a point at which our boat's anchor would set in the bottom; in this way we covered, at each station, approximately 100 ft^2 of bottom area. At most stations, sampling and physical observations had to be made by "feel".

All offshore field operations were conducted from the Department's diving boat *Dolphin*, a 20-ft outboard cabin cruiser.

FINDINGS

Physical Findings

Throughout the study area, except for the jetty rocks, the bottom was gray to black silty sand containing varying amounts of detrital and decaying material. Slightly finer sediments, with greater quantities of decaying matter (evidenced by the presence of hydrogen sulphide), were found in close proximity to the river mouth. The coarsest materials, which included small stones and numerous shell fragments, were found at station IV, between the Seal Beach pier and the Anaheim west jetty.

Surface water temperatures (to 72.2 F station VIII) were abnormally high within the entire study area due to coolant waters being discharged into the river. These warmer waters layered quickly and were not obvious more than 2 to 3 ft beneath the surface 1,300 yards from the river mouth. Cooler, and more normal, temperatures (63.7 F) were recorded beyond the Anaheim east jetty and outside the offshore oil islands (2,800 yards from the river mouth).

The degree and extent of this surface water warming is governed in part by wind and tide. The warm waters are held nearshore and at the river mouth on incoming tides, but spread widely throughout the study area on outgoing tides.

These warm surface waters adversely affect the intertidal biota on the Alamitos Bay east jetty and may be a contributing influence on plankton blooms in the area. Their postulated effect on the round stingray populations near station I already has been mentioned.

Although oily deposits were not visible in the bottom sediments, the substrate samples collected for polychaetes released sufficient oil to form a slight to profuse film on the surface of the preserving liquid. Even after all the animals had been separated from the sediments, by

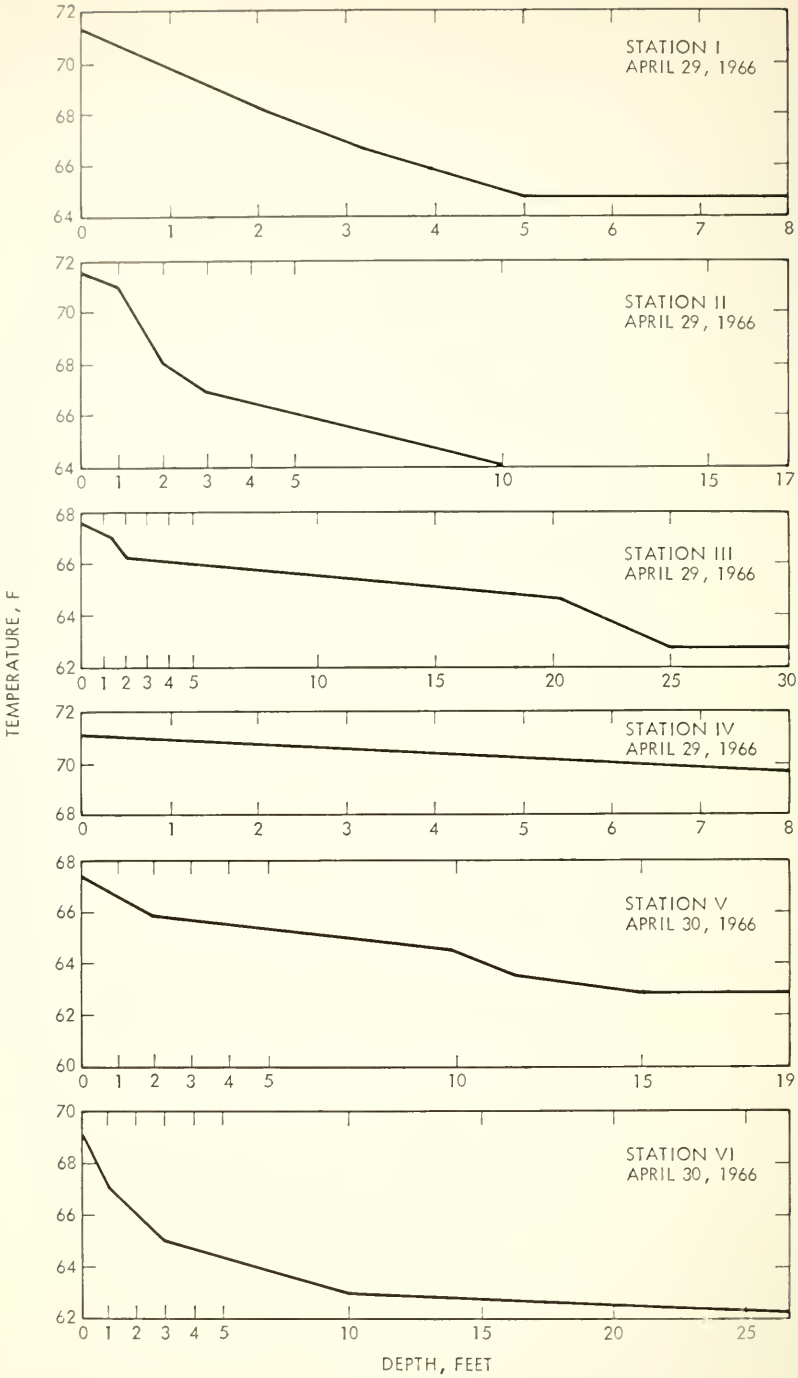

FIGURE 2—Temperature curves as functions of depth in the vicinity of the San Gabriel River mouth, April 1966.

thorough washing and screening, a sample from station IV exhibited this oily film. This oil was not analyzed, since this was beyond the scope of this study, but future work should include a study of its origin, extent, and effect upon the biota.

Water visibilities were limited throughout the study zone, ranging from less than 1 ft at some stations to 4 ft at station IV (Appendix F).

No heavy plankton blooms (red tide) were noted during our field operations (Appendix A).

Biological Findings

Within the general study zone, we conducted biological sampling in three areas: (i) the sand bottom—into 30-ft depths, (ii) the bottom sediments of the river, and (iii) selected sites on the jetties bordering the study zone. Biotic assemblages typical for each bottom type were encountered (Appendixes B, C, and D). The most diverse, colorful, and obvious groupings (19 plants and 81 animals) adhered to the jetty rocks (Appendix B). By contrast, the sand dwellers, typically smaller and less obvious, were seldom noticed during our visual surveys, but detailed examination of the sediment samples revealed an extensive and varied grouping at each station (Appendixes C and D). A notable exception was the poor fauna we found in bottom sediments of stations X and XI near the river mouth. At these two stations, the fine sand was firmly compacted and it was necessary to make several casts with the grab to obtain an adequate sediment sample (about 2 quarts). This condition may have introduced a bias which would account for some reduction in the number of observed species, but not to the extent noted.

The sand bottom stations yielded from 17 (station IV) to 34 species (station III), with an average of 28. Polychaetes dominated all but station I. They accounted for 32 to 64% of the species recorded in each sample, averaging about 52%. At station I, arthropods accounted for 11 of the 25 species (44%). Station IX, a river bottom sample, contained mollusks, arthropods, and annelids in about equal numbers.

Trawling in the general study zone yielded 20 fish and 11 invertebrate species (Appendix E). We have no reasonable explanation for the lack of fishes in our deepest tow (station 5), but the occurrence of fishes with lesions and abraded or missing fins (station 3) probably reflects highly polluted conditions (Young, 1964). Considering the abnormally high number of round stingrays reported nearshore and downcoast from the river jetty, their relative scarcity at our trawling stations was of some interest. We collected only two in April, while the Seal Beach Public Works Department took 800 in three pulls of a 300-ft beach seine on May 19, 1966 (Adolfo Lopes, Seal Beach P.W.D., pers. comm.).

Although we observed many fishes at the westerly jetty of Anaheim Bay, only a blenny was recorded at the east jetty of Alamitos Bay. Hot water from the river may have repelled some fish at the east jetty, but poor water visibility at this station probably was the major reason for our not seeing them.

The invertebrate assemblages on the two jetties were somewhat similar but more species and numbers were recorded at station VII, on

the westerly Anaheim Bay jetty (Appendix B). The intertidal at station VIII, on the easterly Alamitos Bay jetty, differed further in that it was nearly devoid of animals. The water from the river apparently is sufficiently hot to inhibit many intertidal encrusting organisms, and any future increase in the quantity of hot river water will expand this depauperate zone. On the Anaheim Bay west jetty, beyond the influence of these hot waters, luxuriant intertidal encrusting growths were observed.

Algae were not as varied on the jetty rocks as might be expected, and were only moderately luxuriant. The lack of fleshy browns indicated adverse conditions of some sort, perhaps pollutants or reduced water clarity. One alga, *Gymnogongrus leptophyllus*, was dominant, a further indication that inhibiting environmental factors prevail in the area.

DISCUSSION

Our findings indicate that river conditions in 1966 were appreciably better than those reported by Reish (1956). Specifically, our river stations IX, X, and XI yielded 13, 6, and 5 species, respectively (Appendix D), while Reish found only one crustacean at his station 2 (near our station XI), one nemertean at his stations 3 and 4 (on both sides of our station X), two species at station 7, and 11 species at station 8 (both sides of our XI). Where no living animals were found during a California Department of Fish and Game survey in 1952, and 12 species were recorded by Reish in 1954, we found 18. We observed both a greater species diversity and more individuals, indicating a "healthier" environment than previously recorded. Of particular interest was the reduced numbers of capitellid polychaetes in our samples (9 worms), compared with the 340 recorded in 1954. These polychaetes, particularly *Capitella capitata*, have been used to indicate marginal zones of pollution (Donald J. Reish, California State College at Long Beach, pers. comm.), so a decrease in their numbers presumably indicates cleaner waters.

The remaining sand bottom substrate of our study area supported a rich and varied fauna somewhat similar to that reported by Reish and Winter (1954) for Alamitos Bay, indicative of a relatively healthy condition.

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APPENDIX A

Plants and Animals Recorded From Plankton Tows in the Vicinity of the San Gabriel River Mouth, April and May 1966

Scientific name	Station and abundance*							
	I	II	III	IV	V	VI	IX	X
Phytoplankton								
Ceratium sp.	A	S	S	A		S		
Chaetoceros socialis	A	A	A	A	A	A		
Coscinodiscus nitidus				C	C	C	S	S
Centric diatoms, unid.	C		C	C	C	C	S	S
Zooplankton								
Acartia discaudata	A	A	A	A	A		A	A
Cladoceran	S		S	S	C	C		
Eggs, anchovy						S		
Eggs, fish, unid.	C	C	C	C				
Larvae, fish								S
Larvae, lamellibranch				S				
Larvae, nauplius	S		S	S	C	S	C	S
Larvae, polychaete	C		S	S		S		
Larvae, zoea stage of a crab		S						C
Mysids	S						S	C
Sagitta sp.		S	S	S				
Tintinnid, lorica	C	C	C	S	C	C	C	C

* Abundance:
S = Sparse, widely scattered throughout the sample, and nowhere numerous.
C = Common, unevenly present throughout the sample, and only occasionally numerous.
A = Abundant, numerous, and evenly distributed throughout the sample.

APPENDIX B

Plants and Animals Recorded on the Anaheim and Alamitos Bay Jetties April and May 1966

Scientific name	Common name	Station and abundance* VII	VIII	Remarks
Algae				
Cladophora sp.	Green alga	P		
Enteromorpha sp.	Green alga		P	Epiphytic on *Gigartina canaliculata*
Monostroma sp.	Green alga	P		
Ectocarpus sp.	Brown alga		P	
Callithamnion sp.	Red alga	P		
Ceramium pacificum	Red alga	P		Epiphytic on *Monostroma* sp.
Corallina officinalis	Coralline alga	P		
Corallina sp.	Coralline alga		P	
Gigartina canaliculata	Red alga	P	P	
Gigartina spinosa	Red alga	P	P	
Gracilaria or *Gracilariopsis* sp.	Red alga	P	P	Cystocarps not seen; precludes generic indent.
Gymnogongrus leptophyllus	Red alga	A	A	
Lophosiphonia villum	Red alga	P		Epiphytic on *Corallina officinalis*
Microcladia coulteri	Red alga	P		Epiphytic on *Gracilaria* or *Gracilariopsis* sp.
Polysiphonia sp.	Red alga		P	Epiphytic on *Gigartina spinosa* and *Gigartina canaliculata*
Rhodoglossum affine	Red alga	P	P	Epiphytic on *Gigartina spinosa* at station VIII
Rhodymenia arborescens	Red alga	P		
Rhodymenia pacifica	Red alga		P	Epiphytic on *Gigartina spinosa*
Zanardinula lanceolata	Red alga	P	P	
Invertebrata				
Protozoa				
Anomalina sp. (near *grosserugosa*)	Foraminifera		P	
Cnidaria				
Anthopleura elegantissima	Aggregate anemone	6		
Anthopleura sp.	Anemone	3		
Epiactis sp.	Anemone	P		
Muricea californica	Gorgonian	P	P	
Platyhelminthes	Flatworm	1	25	Less than 15 mm at station VIII
Nematoda	Nematode worm	52	P	Less than 5 mm at station VIII
Annelida				
Aphrodita sp.	Polychaete worm		2	
Arabella iricolor	Polychaete worm	8		
Arabella semimaculata	Polychaete worm		2	
Cirratulidae	Polychaete worm	2		
Neanthes succinea	Polychaete worm	2	41	Less than 45 mm; female full of eggs at station VIII
Nereis eakini	Polychaete worm		79	
Platynereis agassizi	Polychaete worm	11		
Nereid unid.	Polychaete worm	1	10	
Harmothöe imbricata	Polychaete worm		7	Less than 20 mm
Harmothöe lunulata	Polychaete worm		10	Less than 20 mm
Harmothöe sp.	Polychaete worm		76	
Phragmatopoma californica	Polychaete worm	P		
Sabellaria cementarium	Polychaete worm		1	
Sabellid unid.	Polychaete worm	8		
Serpula vermicularis	Polychaete worm	2		Epiphytic on *Tetraclita squamosa rubescens*
Syllidae	Polychaete worm		1	
Hirudinea	Leech	3		
Arthropoda				
Balanus glandula	Acorn barnacle	96	P	
Tetraclita squamosa rubescens	Acorn barnacle	16		
Mitella polymerus	Stalked barnacle	1	P	

APPENDIX B—Continued

Plants and Animals Recorded on the Anaheim and Alamitos Bay Jetties April and May 1966

Scientific name	Common name	Station and abundance* VII	VIII	Remarks
Chelifera Tanaidacea		6	9	
Isopoda			9	
Gammaridea	Amphipod	230+	47	
Caprella angusta	Amphipod	30+		
Caprella verrucosa	Amphipod	1340+	4	Female bearing eggs in all stages at station VII; 3 males and 1 female at station VIII.
Spirontocaris palpator	Shrimp		1	
Cancer antennarius	Crab	3	3	Less than 20 mm
Pachygrapsus crassipes	Shore crab	A	2	
Pagurus samuelis	Hermit crab		1	In the shell of *Jaton festivus*
Pugettia producta	Crab	1	1	Less than 20 mm at station VIII
Ammothella spinifera	Sea spider		7	
Mollusca				
Nuttallina californica	Chiton	2		
Acmaea digitalis	Limpet	P		
Acmaea scabra	Limpet	5		
Acmaea sp.	Limpet	S		
Crepidula onyx	Slipper snail		9	Less than 25 mm
Haliotis cracherodii	Black abalone		1	
Lottia gigantea	Owl limpet	2		70 mm
Megathura crenulata	Keyhole limpet	3		
Mitrella carinata	Keeled snail	16	13	Less than 10 mm at station VIII
Mitrella gouldi	Snail		1	Less than 10 mm
Mitrella tuberosa	Snail	2		
Mitrella sp.	Snail	P		
Ocenebra poulsoni	Rock snail		S	Less than 25 mm
Olivella biplicata	Olive snail		1	
Rissoella sp.	Snail	2		
Serpulorbis squamigerus	Tube-building snail	P		
Hiatella arctica	Rough nestling clam	S	70	Less than 15 mm at station VIII
Lima hemphilli	File snail		6	Less than 10 mm
Mytilus californianus	Mussel	1	P	
Mytilus edulis	Bay mussel	22	166	Less than 20 mm at station VIII
Flabellina iodinea	Aeolid nudibranch		1	
Aeolid unid.	Aeolid nudibranch		2	
Nudibranch unid.			6	
Ectoprocta				
Anguinella palmata	Bryozoan		P	
Crisia occidentalis	Bryozoan	P	P	
Holoporella brunnae	Bryozoan	P		
Membranipora tuberculata	Bryozoan	P	P	Epiphytic on *Gigartina spinosa*, *G. canaliculata* and *Gymnogongrus leptophyllus* and *Zanardinula anceolata* at station VII; on *Gigartina spinosa*, *G. canaliculata* and *Gymnogongrus leptophyllus* at station VIII.
Victorella argilla	Bryozoan	A		On all lower stones into 10-ft depths; abundant on *Muricea californica* near the sand-rock interface.
Thalamoporella californica	Bryozoan		P	Epiphytic on *Gigartina spinosa* and *G. canaliculata*
Echinodermata				
Ophiactis sp.	Brittle star	10	31	Less than 20 mm at station VIII
Patiria miniata	Sea star	65	1	
Pisaster ochraceus	Sea star	3	1	
Strongylocentrotus purpuratus	Sea urchin	1		
Ascidiacea				
Cystodytes lobatus	Compound ascidian	P		

APPENDIX B—Continued

Plants and Animals Recorded on the Anaheim and Alamitos Bay Jetties April and May 1966

Scientific name	Common name	Station and abundance*		Remarks
		VII	VIII	
Vertebrata				
Atherinops affinis	Topsmelt	40+		
Embiotoca jacksoni	Black perch	42		
Gibbonsia sp.	Kelpfish	1		
Girella nigricans	Opaleye	25		
Hypsoblennius sp.	Blenny	5	1	
Hypsypops rubicunda	Garibaldi	1		
Phanerodon furcatus	White seaperch	3		
Rhacochilus toxotes	Rubberlip perch	3		

* Abundance within the 100-ft² study area:
P = Present in the area but relative abundance not estimated.
A = Abundant, numerous, and evenly distributed throughout the area.

APPENDIX C

Invertebrates Recorded From a 1-Quart Sample of Bottom Sediments Taken in the Vicinity of the San Gabriel River Mouth, April and May 1966

Scientific name	Common name	Station and abundance*						Remarks
		I	II	III	IV	V	VI	
Protozoa								
Gromia oviformis	Testate protozoan	1		1				
Cnidaria								
Pennatulacea	Sea pen			1				
Annelida								
Ampharetidae	Polychaete worm			1				
Arabellidae	Polychaete worm		2	1			1	
Capitellidae	Polychaete worm		2	11				Plus numerous fragments at station III
Cirratulidae	Polychaete worm					1	2	
Eunicidae	Polychaete worm		5	4	1			
Flabelligeridae	Polychaete worm			1				
Glyceridae	Polychaete worm	1						
Goniada brunnea	Polychaete worm	1		2			1	
Nephtys caecoides	Polychaete worm		1	4				
Nephtys californiensis	Polychaete worm	5			3		3	
Nephtyid unid.	Polychaete worm		10	9		1		Juveniles, near *Nephtys californiensis*, at station III
Diopatra ornata	Polychaete worm		S	1			P	
Diopatra sp.	Polychaete worm	6				11		
Owenia sp.	Polychaete worm	4		2	2			
Cistenides brevicoma	Polychaete worm				1			
Pectinaria californiensis	Polychaete worm		3					Plus 3 empty tubes at station II
Pectinarid unid.	Polychaete worm		A	S		6	1	Plus tube fragments at stations III and VI
Serpulidae	Polychaete worm						1	
Prionospio pinnata	Polychaete worm			1				
Spionid unid.	Polychaete worm	11	1	1	4	2	4	
Polychaete unid.	Polychaete worm			2				
Sipunculida	Sipunculid worm	5	4	2			1	Juvenile at station II
Arthropoda								
Ostracoda	Crustacean	22		4	2	5	5	
Diastylis californica	Cumacean	156	7		10	17	3	
Cumacean unid.		5	5	4	2	1		
Asellota	Isopod		1	2			1	
Isopod unid.		15			2			
Gammaridea	Amphipod	37	6	7	7	5	4	
Brachyura	Crab	1	1					Fragments at station I
Callianassa sp.	Hermit crab						1	Juvenile
Callipallene palpida	Sea spider	4			7			
Pycnogonid unid.	Sea spider	6						
Mollusca								
Cyclostremella californica	Snail					2		
Donax sp.	Clam	1	12		1	2	6	Juveniles less than 2 mm
Macoma secta	Pelecypoda		1	2		2	2	Juveniles
Phoronida	Phoronid worm	2					A	

* Abundance:
P = Present in the sample but relative abundance not estimated.
S = Sparse, widely scattered throughout the sample but nowhere numerous.
A = Abundant, numerous, and evenly distributed throughout the sample.

APPENDIX D

Invertebrates Recorded From Orange-Peel Grab Samples Taken in the Vicinity of the San Gabriel River Mouth, April and May 1966

Scientific name	Common name	Station and abundance*									Remarks
		I	II	III	IV	V	VI	IX	X	XI	
Protozoa											
Gromia oviformis	Testate protozoan		16								
Cnidaria											
Isanthid	Anthozoan					7		26	1		Small unidentified anemone
Platyhelminthes	Flatworm		1			1		1			
Nemertina											
Tubulanus pellucidus	Nemertean worm					8					
Nemertean unid.	Nemertean worm			27	2		6	1		1	
Annelida											
Ampharetidae	Polychaete worm			1							
Aphroditidae	Polychaete worm						1				
Arabella semimaculata	Polychaete worm					2					
Drilonereis nuda	Polychaete worm					1					
Arabella sp.	Polychaete worm						1				
Arabellid unid.	Polychaete worm		4	6					2		
Arenicolidae	Polychaete worm		3								
Capitellidae	Polychaete worm		73	17		28	5		9		
Cirratulidae	Polychaete worm						2				
Dorvilleidae	Polychaete worm						6				
Eunicidae	Polychaete worm		63	37							
Glycera tenuis	Polychaete worm					1					
Hemipodus borealis	Polychaete worm					2					
Glycerid unid.	Polychaete worm			1					1		
Goniada brunnea	Polychaete worm	7	10	11		11	9				
Goniadid unid.	Polychaete worm		1								
Nephtys caecoides	Polychaete worm				1						
Nephtys californiensis	Polychaete worm		18			2					
Nephtyid unid.	Polychaete worm			15			1				
Nereis eakini	Polychaete worm							61			
Nereid unid.	Polychaete worm			9							
Diopatra ornata	Polychaete worm		4			8	11				Station VI—tube fragments
Diopatra sp.	Polychaete worm			10	3		11				Station VI—tube fragments
Ophelia limacina	Polychaete worm						1				
Opheliid unid.	Polychaete worm			1							
Orbinia johnsoni	Polychaete worm		1			1					
Orbiniid unid.	Polychaete worm			5							
Owenia sp.	Polychaete worm	2									
Cistenides brevicoma	Polychaete worm					41					
Pectinaria californiensis	Polychaete worm		7								Plus three empty tubes
Pectinariid unid.	Polychaete worm	1		2							
Pilargiidae	Polychaete worm						2				
Polynoidae	Polychaete worm	1	1				1				
Polyodontidae	Polychaete worm						1				
Chone mollis	Polychaete worm					4					
Sabellid unid.	Polychaete worm			2							
Serpulidae	Polychaete worm		2			2	2				
Boccardia proboscidea	Polychaete worm							149			
Prionospio pinnata	Polychaete worm		4								
Spionid unid.	Polychaete worm	12	27	30	1	1	30	5		14	
Amaea sp.	Polychaete worm					1					
Polychaete unid.				4							
Hirudinea	Leech							1			
Echiuroidea											
Listriolobus pelodes	Echiuroid					1					
Sipunculida	Sipunculid worm		5	5					1		
Priapuloidea	Priapuloid					2					

APPENDIX D—Continued

Invertebrates Recorded From Orange-Peel Grab Samples Taken in the Vicinity of the San Gabriel River Mouth, April and May 1966

Scientific name	Common name	Station and abundance*									Remarks
		I	II	III	IV	V	VI	IX	X	XI	
Arthropoda											
Ostracoda	Crustacean	38		4		4	1				
Mysidacea	Crustacean									2	
Diastylis californica	Cumacean	117	9	1		22	1				
Cumacean unid.	Cumacean	4									
Asellota	Isopod	3									
Valvifera	Isopod					3					
Isopod unid.								100 +			
Gammaridea	Amphipod	7	15	15		10	17	500 +			
Caprella equilibra	Caprellid amphipod							9		3	
Tritella sp.	Caprellid amphipod	1									
Caprellid unid.	Caprellid amphipod								2		
Brachyura	Crab					1					
Callianassa sp.	Hermit crab		1								
Holopagurus pilosus	Hermit crab				1						
Pinnixa tubicola	Crab						1				
Callipallene palpida	Sea spider									11	
Phoxichilus compactus	Sea spider	2									
Mollusca											
Acteocina culcitella	Snail					1					
Acteocina sp.	Snail					4		25			
Barleeia sp.	Rissoid snail					1					Commensal organisms attached, unidentified
Conus californicus	Cone snail						1				
Crepidula adunca	Hooked slipper snail				1		1				
Cyclostremella californica	Snail	3	1			28					
Epitonium sp.	Wentletrap snail					2					
Polinices reclusianus	Moon snail				1						
Chione sp.	Clam					3					
Donax sp.	Clam	3	3			19					
Macoma secta	Pelecypod	7	4			23		1			
Pectinidae	Pelecypod		1								
Siliqua lucida	Clam							1			
Ectoprocta											
Crisia occidentalis	Bryozoan	P									Small pieces
Triticella sp. (near *pedicellata*)	Bryozoan						A				
Phoronida	Phoronid worm	1		1		6					
Brachiopoda											
Glottidia albida	Brachiopod			2			1				
Echinodermata											
Ophiuroidea	Brittle star			1							
Holothuroidea	Sea cucumber						1				

* Abundance:
P = Present but not enumerated.
A = Abundant, numerous, and evenly distributed throughout the sample.

APPENDIX E

Fishes and Invertebrates Collected by Trawling in the Vicinity of the San Gabriel River Mouth, April 25, 1966

Scientific name	Common name	Station (depth in ft)					
		1 (15)	2 (10–12)	3 (20)	4 (6)	5 (30)	6 (6–8)
		Number per station (total lenght in mm)					
FISHES							
Rhinobatos productus	Shovelnose guitarfish	2(282–322)	--	--	2(280–385)	--	2(315–332)
Platyrhinoidis triserata	California thornback	1(272)	--	--	--	--	--
Urolophus halleri	Round stingray	1(149)	--	--	1(415)	--	2(144–239)
Anchoa compressa	Deepbody anchovy	--	1(110)	--	1(100+)	--	--
Engraulis mordax	Northern anchovy	--	--	17(50–115)	--	--	--
Citharichthys sordidus	Pacific sanddab	1(125)	--	1(140)	1(115)	--	--
Paralichthys californicus	California halibut	--	--	1(457)	5(113–457)	--	--
Hypsopsetta guttulata	Diamond turbot	1(200)	--	--	1(210)	--	1(211)
Symphurus atricauda	California tonguefish	--	--	6(147–182)	--	--	--
Paralabrax nebulifer	Sand bass	--	--	--	1(175)	--	--
Amphistichus argenteus	Barred surfperch	4(75–240)	--	--	25(55–230)	--	57(53–170)
Cymatogaster aggregata	Shiner perch	--	--	--	--	--	2(115–135)
Hyperprosopon argenteum	Walleye surfperch	--	--	16(55–61)	26(58–115)	--	--
Phanerodon furcatus	White seaperch	2(55–190)	13(56–233)	*3(135–217)	9(146–215)	1(169)	19(131–245)
Cheilotrema saturnum	Black croaker	--	1(298)	--	--	--	--
Menticirrhus undulatus	California corbina	--	--	--	7(70–140)	--	12(103–265)
Seriphus politus	Queenfish	†188(60–170)	--	133(70–165)	2(140–200)	--	--
Genyonemus lineatus	White croaker	7(27–210)		‡15(100–264)	2(170)	--	--
Syngnathus sp.	Pipefish	--	§1(220)	1(226)	¶1(184)	--	--
Otophidium scrippsi	Cusk-eel	--	--	2(240–245)	--	--	--
INVERTEBRATES							
Lironeca vulgaris	Isopod	Numerous	--	Numerous	Numerous	--	--
Pterisopodus bartschi	Isopod	2	--	Several	3	--	--
Crago nigromaculata	Shrimp	60	*2(30–40)	15(30–40)	--	--	--
Pulaemonetes hiltoni	Shrimp	1(45)	--	--	--	--	--
Pyromaia tuberculata	Crab	1	--	--	--	--	--
Cancer anthonyi	Yellow crab	2(11–28)	--	--	--	--	--
Holopagurus pilosus	Hermit crab	Several	--	--	--	--	--
Aplysia californica	Sea hare	1 and eggs	Egg mass	Egg mass	--	--	--
Flabellina iodinea	Aeolid nudibranch	--	--	--	--	3	--
Polinices reclusianus	Moon snail	--	--	--	--	1	--
Astropecten armatus	Sand star	--	--	--	--	1	--
Detritus and algal material		X	--	X	--	--	X

* One with tail rotted off.
† Majority of these less than 100 mm long.
‡ 10 with tails rotted off.
§ Male with eggs, station 2.
¶ Gravid female, station 4.

APPENDIX F

Physical Data for the Stations Occupied During a Survey of the Marine Environment in the Vicinity of the San Gabriel River Mouth, April and May 1966

Station	Dat	Depth (ft)	Temperature F		Diver estimated visibility (ft)		Remarks
			Bottom	Surface	Bottom	Surface	
1	April 25, 1966	15	--	--	--	--	Trawl track; approximately 700 yd; San Gabriel River mouth toward Seal Beach Pier. Much drift algae in the net.
2	April 25, 1966	10-12	--	--	--	--	Trawl track; approximately 700 yd; Seal Beach Pier to San Gabriel River mouth.
3	April 25, 1966	20	--	--	--	--	Trawl track; approximately 1,900 yd; Alamitos Bay easterly jetty to Anaheim Bay westerly jetty. Moderate detritus in the net.
4	April 25, 1966	6-10	--	--	--	--	Trawl track; approximately 700 yd; Anaheim Bay westerly jetty to Seal Beach Pier.
5	April 25, 1966	30	--	--	--	--	Trawl track; approximately 1,900 yd; offshore Anaheim Bay westerly jetty to offshore Alamitos Bay easterly jetty.
6	April 25, 1966	6-8	--	--	--	--	Trawl track; approximately 1,900 yd; Alamitos Bay westerly jetty toward Belmont Pier. Much detritus in the net.
I	April 28, 1966	8	64.6	71.4	0.25	2	Uniform gray silty sand bottom. Much detrital material; ripples 0.5 to 1 cm high; east-west alignment. Core: 11.5 inches long; uniform gray silty sand; evidence of H_2S at 6.5 to 7 inches and 8 to 8.5 inches. Much sediment in suspension near bottom.
II	April 28, 1966	17	64	71.6	<1	<1.5	Core: 12.5 inches; gray brown silt, top 6 inches. Dark black H_2S smelling silt last 6.5 inches. Length of core limited by tube length—very soft bottom.
III	April 28, 1966	30	62.8	67.6	2-3	2-3	Core: 16 inches; uniform gray-black silty mud.
IV	April 28, 1966	8	69.8	71.2	4	4	Core: 8 inches; uniform gray sand. Much shelly debris on the bottom.
V	April 29, 1966	19	62.8	67.5	<1	1	Firm, silty mud; 0.25 to 0.5 cm high ripples; east-west alignment; worm castings on slope and peaks. Core: 8 inches; top 3 inches yellowish sandy silty; bottom 5 inches blackish with H_2S odor.
VI	April 29, 1966	27	62.2	69.1	<1	1	Black silty mud; suspended silt on bottom in motion with surge. Core: 15 inches; uniform black silty mud.
--	April 29, 1966	--	--	63.7	--	--	Surface temperatures taken 2,400 yd south and again 2,000 yd east of end of Seal Beach Pier. Both locations apparently outside the influence of the river's discharge.
VII	April 29, 1966	15	64.6	66.4	3	3	Sampling on rocks of Anaheim Bay westerly jetty, 0- to 15-ft depths.
VIII	May 3, 1966	15	63.3	72.7	1-2	1-2	Sampling on rocks of Alamitos Bay easterly jetty; 0- to 15-ft depths.
IX	May 17, 1966	--	--	--	--	--	Orange-peel grab and plankton samples: Pacific Coast Highway bridge.
X	May 17, 1966	--	--	--	--	--	Orange-peel grab and plankton samples: Marina Drive bridge.
XI	May 17, 1966	--	--	--	--	--	Orange-peel grab and plankton samples: middle of river mouth.

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OBSERVATIONS ON SURVIVAL AND GROWTH OF THE EUROPEAN FLAT OYSTER, *OSTREA EDULIS*, IN CALIFORNIA[1]

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Growth and survival experiments were conducted with the European flat oyster in Drakes Estero, Tomales Bay, Morro Bay, and Elkhorn Slough for a 3½-year period commencing in May 1963. Survival was poor in all areas except Tomales Bay. Growth cessation was noted in all areas and was especially evident in the 1963 and 1964 year classes. An organism believed to be responsible for the poor growth and survival of this oyster was observed.

INTRODUCTION

Attempts to grow the European flat oyster, *Ostrea edulis*, in California were initiated in Tomales Bay and Drakes Estero in 1962. Growth and survival of this species appeared promising (Dahlstrom, 1964). Additional shipments were obtained from the U.S. Fish and Wildlife Laboratory at Milford, Connecticut, in May and November 1963, November 1964, and October 1965 for further studies on the growth and survival of this species in California waters. Plants were made in Tomales Bay, Drakes Estero, and Morro Bay. After approximately 5 months, part of the oysters originally planted in Tomales Bay were transferred to Elkhorn Slough.

METHODS

Oysters from all shipments were placed in wire mesh trays and suspended from racks in Drakes Estero, Tomales Bay, and Morro Bay as described by Dahlstrom (1964). At Elkhorn Slough, similar baskets were suspended above the bottom on redwood stakes at approximately the +1.0-ft tidal level. These oysters were measured at varying intervals during the year to determine shell growth (using shell length as the growth index). Later in the study, samples were taken for histological examination. These oysters were fixed in Davidson's solution, processed using standard histological techniques, and stained with haematoxylin and eosin.

RESULTS

Tomales Bay

One hundred and nine oysters from the 1963 Milford shipment (1962 year class) were placed in Tomales Bay; survival of these oysters after 1, 2, and 3 years was 88%, 68%, and 57%, respectively. Growth ceased after 2 years, when the oysters reached an average

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length of 90 mm. The 1964 Milford shipment (1963 year class) was placed on the rack adjacent to the 1963 shipment. Survival of these oysters (125 individuals) was 89% after 1 year and 49% after 2½ years. Growth ceased after 1 year, when the oysters averaged 65 mm in length. The 1965 Milford shipment (289 oysters of the 1964 year class) was placed adjacent to the oysters of the previous two shipments. Survival of these oysters was 99% after 1 year and 73% after 2 years. Growth stopped after 1 year, when these oysters averaged 68 mm in length.

Drakes Estero

Survival of the 1963 Milford shipment (121 oysters) was 31% after 2½ years; however, most of the mortalities occurred during the first year and were attributed to crab predation. These oysters reached an average length of 90 mm in the 2½-year period. One hundred and twenty-five oysters of the 1964 Milford shipment were placed adjacent to the 1963 shipment. These oysters had a survival rate of 81% during the first year; however, the mortality rate increased drastically during the next 12 months, with only 5% of the original population surviving. These oysters reached an average length of 62 mm in 15 months, after which no growth was observed. Oysters of the 1965 Milford shipment (302 individuals) were placed adjacent to the oysters of the previous two shipments. Survival after 18 months was only 5%. Approximately 25% of the mortality incurred by the 1965 shipment was attributed to crab predation. Growth ceased after 1 year, when the oysters averaged 67 mm in length.

Morro Bay

Five hundred and thirty-six oysters from the November 1963 Milford shipment were placed in Morro Bay; however, 329 individuals were removed for other studies; of the remainder, 86%, 80%, and 9% survived 1, 2, and 3½ years, respectively. These oysters reached an average length of 93 mm in 2½ years then grew no more. One hundred and forty-eight oysters from the 1964 Milford shipment were placed adjacent to the 1963 shipment. Losses among this population were heavy, with only 26% surviving 12 months and 13% surviving 18 months. These oysters reached an average length of 67 mm in 1 year, then stopped growing. Survival of the 1965 Milford shipment (297 oysters) was 87% for the first year, but heavy mortalities occurred during the next 6 months and at the end of 1½ years only 12% of the original population remained alive. No growth was observed after 10 months, when the oysters reached an average length of 75 mm.

Elkhorn Slough

In March 1966, 298 oysters from the 1965 Milford shipment were transferred from Tomales Bay to Elkhorn Slough. Mortality rates were very high and the entire population succumbed within 12 months.

HISTOPATHOLOGY

In view of the growth cessation and poor survival exhibited by the experimental populations, a sample of live oysters was forwarded to the U.S. Bureau of Commercial Fisheries Laboratory at Oxford, Mary-

land, in December 1965 for examination. Its specialists observed an organism closely resembling one associated with Pacific oyster, *Crassostrea gigas*, mortalities on the west coast of Canada (C. J. Sindermann, U.S. Bureau of Commercial Fisheries Laboratory, Oxford, Md., pers. comm.). They described the organism as a 2-μ to 3-μ cell, containing a single small nucleus of approximately 0.8μ. Their observations indicated that the organism was cytozoic within leucocytes (as many as 15 parasites were observed in a single leucocyte) or was free in the blood; division appeared to be amitotic. Beginning in the summer of 1966, the California Department of Fish and Game's Oyster Disease and Mortality Study further investigated this problem. The experimental populations were at a low level at this time; nevertheless, limited numbers of oysters were available from all areas for histological examination. Of 30 oysters from Drakes Estero (including all year classes), 13 (approximately 36%) were infested by the organism (Figure 1) described by Sindermann, hereafter referred to as a microcell. Grossly, these oysters were thin, watery, and transparent. Histologically, they exhibited a

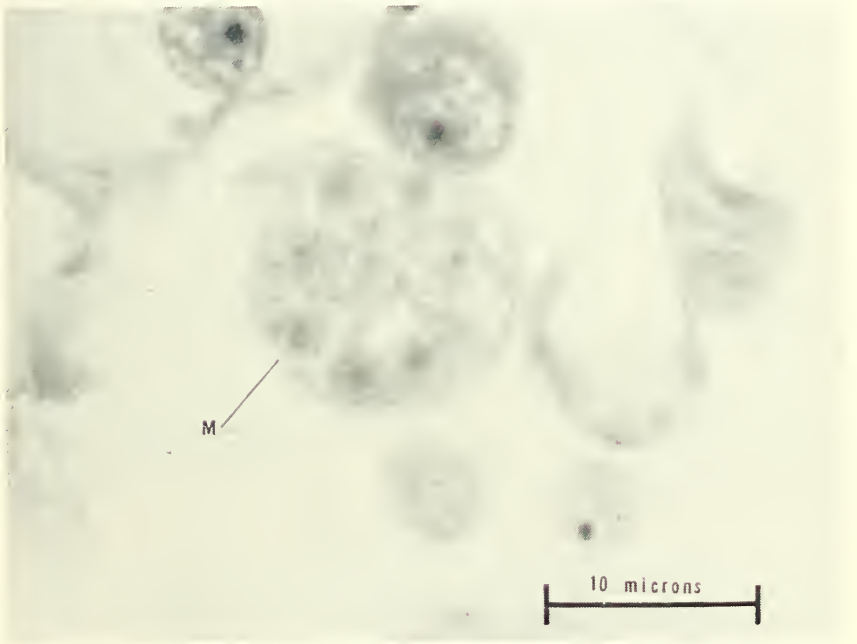

FIGURE 1—Photomicrograph of microcells cytozoic with a leucocyte (M = microcell).

generalized leucocytic infiltratiton which was particularly evident in the area of the digestive tubules. The digestive tubules generally lacked the normal crypt structure, with the epithelial cells being reduced to a low cuboidal epithelium similar to the condition described by Pauley and Sparks (1965) in their studies of the acute inflammatory reaction in Pacific oysters. Similar gross and histological observations were made on oysters collected at Morro Bay and Elkhorn Slough. Fourteen of 48

oysters (approximately 29%) from Morro Bay and 11 of 19 oysters (approximately 57%) at Elkhorn Slough were infested by microcells. A few gapers (dead oysters with soft parts intact) were available for examination and all were infested by microcells. Only 18 oysters from Tomales Bay were studied histologically and none was infested by microcells. It should be remembered that the survival of oysters at Tomales Bay was considerably higher than at the other study areas.

Reproduction of microcells, indicated by binucleated cells and cells with single dumbbell-shaped nuclei, was noted in oysters collected from Elkhorn Slough in February 1967 (Figure 2).

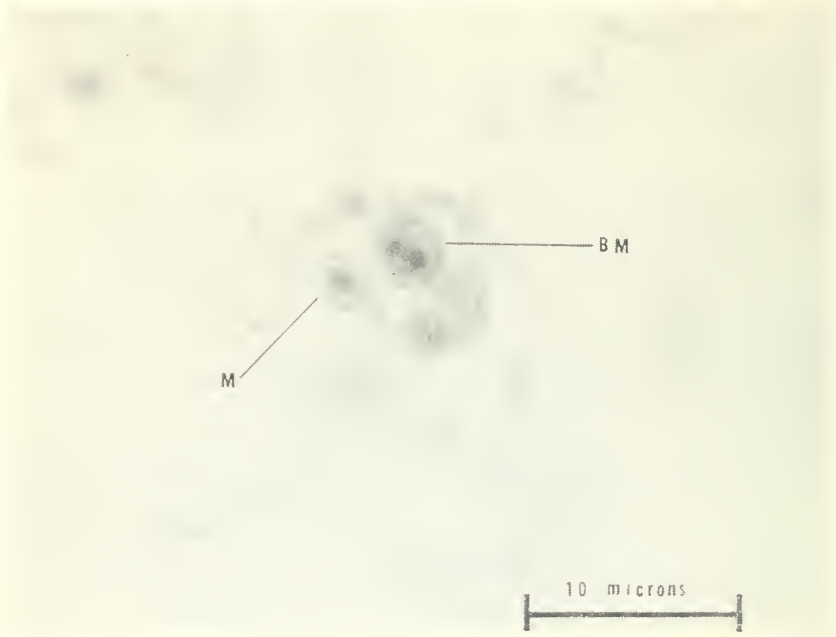

FIGURE 2—Photomicrograph of binucleate microcell (BM = binuclected microcell, M = microcell).

DISCUSSION

The original optimism for the culture of European flat oysters in California, based on the pilot study of 1962, is not supported by our study. Tomales Bay appears to be the only area studied where this oyster can be grown, but there is some doubt whether even here the alleged pathogen (the microcell) is totally absent. While the oyster survival rate was much higher in Tomales Bay, the same growth cessation as in the other areas was observed. Microcells may have been present in numbers too low to be detected by the relatively few oysters we examined but in numbers great enough to affect growth. The absence or lower intensity of microcell infestation also might explain the higher survival rate in Tomales Bay.

The origin of microcells in oysters is of considerable interest, for two reasons. First, if microcells were present in the oysters before importa-

tion to California, their introduction and apparent pathogenicity create an extreme danger to existing stocks of oysters and possibly other shellfish. Stocks of Pacific oysters immediately adjacent to infested European flat oysters showed no signs of distress, but microcells were found in Portuguese oysters, *Crassostrea angulata*, within 2 months after exposure to the infested stocks of European flat oysters. Secondly, if microcells are endemic to California, then only susceptible stocks of shellfish (i.e., certain stocks of European flat oysters) would be adversely affected. However, heavy infestations, observed in some stocks of European flat oysters, might increase the intensity of the so far "benign pathogen" in the environment to the point where previously uninfested species (i.e., Pacific oysters) would become endangered. Sindermann stated that these microcells resembled an organism associated with mortalities of Pacific oysters on the west coast of Canada, and they also resemble an organism associated with eastern oyster, *Crassostrea virginica*, mortalities on the east coast of Canada (J. A. Mackin, Texas A. & M. U., College Station, Texas, pers. comm.). The origin of the microcells in California is uncertain; it is increasingly evident that microcells (and/or similar organisms) have an infective capacity for quite a number of commercially important hosts. Certainly, additional information about this alleged pathogen is needed before random movements of susceptible oysters create circumstances detrimental to commercial populations.

There is some evidence that other "races" of European flat oysters may be more acceptable to culture in California than those used in our study. A European flat oyster stock was received (135 oysters) from Kesennuma, Japan, in March 1964 (1963 year class) and placed in Drakes Estero adjacent to the Milford oysters. The initial mortality in this group of oysters was heavy, with only 59% surviving the first 2 months after introduction. Approximately 30% of this shipment remained alive after 1 year. The high initial mortality rate was attributed to the weakened condition of the seed. Most of the losses between the 3rd and 12th months were attributed to crab predation. After this first disastrous year, only two oysters were observed to succumb and these were noted after a 2½-year period of no mortality. The Milford oysters which were immediately adjacent to this stock experienced very heavy mortalities during this period. Ten of the surviving Kesennuma oysters were examined histologically and only one exhibited a light microcell infestation. A similar plant was made in Tomales Bay in March 1965 (1964 year class). The same initial losses were noted, with 54% survival after 1 year and 38% survival after 2½ years. These oysters showed a period of reduced growth during the summer of 1966, but growth rates increased after this time. These oysters reached an average length of 92 mm during the study. The analogous year class from Milford did not reach this size and a definite growth cessation was noted. It appears that successful culture of European flat oysters in California will have to be from a hardy "race", such as the oysters from Kesennuma or their progeny.

ACKNOWLEDGMENTS

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STOMACH CONTENTS OF PACIFIC HAKE AND ARROWTOOTH FLOUNDER FROM NORTHERN CALIFORNIA[1]

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Stomach contents from 16 species of fishes were examined during July, August, and September 1964, to determine which species fed heavily on ocean shrimp, *Pandalus jordani*. A large proportion of Pacific hake, *Merluccius productus*, and arrowtooth flounder, *Atheresthes stomias*, contained ocean shrimp in their stomachs, so they were selected for a 1-year study. In all, 527 Pacific hake and 425 arrowtooth flounder stomachs were examined during the study period. Ocean shrimp constituted the dominant organism in the stomachs of both the hake and flounder, and the author believes that the vertical migrations of Pacific hake may correspond with veritical migrations of ocean shrimp at night.

INTRODUCTION

I have suspected that the food habits of a predator of ocean shrimp, *Pandalus jordani*, might provide information about the relative abundance of an incoming year class of this species as well as provide data about growth rates. During July, August, and September 1964, the stomachs from 16 species of fishes were collected and examined to determine possible predator-prey relationships (Table 1). I decided that the stomach contents of Pacific hake, *Merluccius productus*, and arrowtooth flounder, *Atheresthes stomias*, caught incidentally with ocean shrimp might provide the required information about the species.

In the spring of 1965, a series of sea surveys was initiated to study the population dynamics of the ocean shrimp in northern California waters (Figure 1). As a result of this investigation and the study of the ocean shrimp found in the Pacific hake stomachs, considerable information was gathered concerning the mortality rates and relative abundance of the incoming year class of ocean shrimp (Gotshall, 1967).

METHODS

Stomachs were obtained from fish caught on the shrimp bed (Figure 1) in various otter trawls, including those of commercial shrimp vessels (1½-inch stretch mesh), bottomfish trawlers (4½-inch stretch mesh), and California Department of Fish and Game research vessels *N. B. Scofield* and *Alaska*. The research vessels fished a 41-ft head rope semiballoon Gulf shrimp trawl constructed of 1-inch stretch mesh with a ½-inch stretch mesh liner placed in the cod end.

Each fish was identified and its total length, sex, date, and location of capture was recorded. The stomachs were then removed and preserved in 70% isopropyl alcohol. Stomach contents were examined under a dissecting microscope, the organisms were measured and

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TABLE 1

Frequency of Occurrence of Seven Food Items Found in the Stomachs of 16 Species of Fishes Collected Off Northern California, July–September 1964

Species	Size range (mm TL)	Stomachs examined: Total number	Stomachs examined: Number empty	Food items and the number of stomachs containing them: Ocean shrimp	Krill	Misc. crustaceans	Fishes	Clams	Polychaete worms	Brittle stars
Sanddab	112–654	2	0	--	--	1	2	--	--	--
Pacific hake	100–815	164	31	97	67	9	19	1	2	--
Jack mackerel	562	1	0	--	1	--	--	--	--	--
Petrale sole	346–500	11	0	7	5	1	--	--	--	--
Dover sole	400–514	11	3	--	--	--	1	1	6	4
Slender sole	206–246	4	0	--	4	--	--	--	--	--
Arrowtooth flounder	322–616	15	2	10	3	--	2	--	--	--
Chilipepper	269–530	9	1	--	8	--	--	--	--	--
Widow rockfish	450	1	1	--	--	--	--	--	--	--
Yellowtail rockfish	460–505	2	0	1	1	--	1	--	--	--
Canary rockfish	500	1	0	--	1	--	--	--	--	--
Pacific ocean perch	294	1	1	--	--	--	--	--	--	--
Stripetail rockfish	241–334	6	0	5	1	1	--	--	--	--
Greenstripe rockfish	211–378	6	3	3	--	--	--	--	--	--
Flag rockfish	470–538	2	0	2	--	1	1	--	--	--
Sablefish	398–580	6	1	5	4	--	--	--	--	--

counted, and their volumetric displacement was determined in a graduated cylinder. Organisms found in the mouths and throats of the fish were discarded. Stomach parasites have not been included in the discussion or tables.

RESULTS

Arrowtooth Flounder

Arrowtooth flounder stomachs were collected monthly from September 1964 to October 1965 (Table 2). During this period, 172 of the 425 stomachs examined were empty. All those collected during March were empty. Stomachs collected in December 1964 were obtained from commercial bottomfish trawlers fishing in 185 fathoms west of Eureka, California (lat. 40° 50′ N, long. 124° 27′ W). Stomachs were examined from fish ranging in size from 132 mm to 790 mm TL.

Crustaceans were the most common food items and contributed the largest volume (Table 3). Krill (Euphausiacea), shrimp, ocean shrimp, and small market crabs were the predominant crustaceans. Ocean shrimp were not found in the stomachs during November 1964 or February and March 1965. While fish were found throughout the year, they tended to be the dominant food items during November and December. Pacific sanddabs were the most numerous of the 10 species of fishes identified, followed by slender sole and rex sole. The average volumes per stomach in December and February were the highest observed during the entire study period.

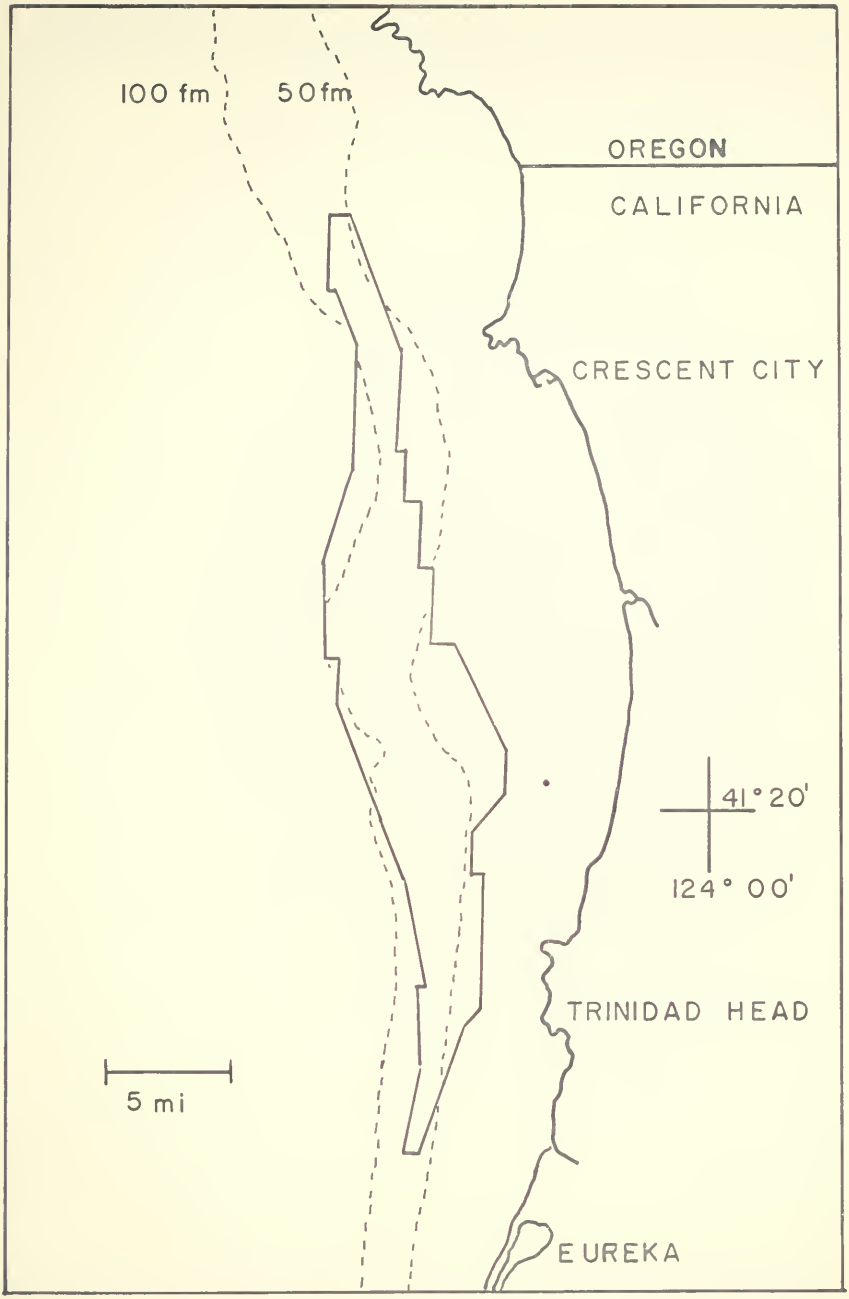

FIGURE 1—Northern California ocean shrimp survey area, March 1965–September 1967.

TABLE 2

Frequency of Occurrence of 20 Food Items in Arrowtooth Flounder Stomachs Collected Off Northern California, September 1964–October 1965

Food item	Number of stomachs containing food item													Totals
	Sept.	Oct.	Nov.	Dec.*	Feb.†	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	
Snails	--	1	--	--	--	--	--	--	--	--	1	--	--	2
Krill	3	--	--	--	--	--	2	3	34	7	--	--	12	61
Shrimp	--	2	--	--	--	--	1	4	11	17	8	3	7	53
Ocean shrimp	10	6	--	2	--	--	1	6	12	38	17	7	19	118
Market crab	--	2	--	1	1	--	--	1‡	--	--	--	--	--	5
Eulachon	--	--	--	1	--	--	1	--	--	1	--	--	--	3
Whitebait smelt	--	--	--	--	--	--	--	--	--	--	1	--	1	2
Night smelt	--	--	--	--	--	--	--	--	--	--	--	--	1	1
Pacific tomcod	--	--	--	--	--	--	--	--	--	--	1	--	--	1
Speckled sanddab	--	--	--	--	--	--	--	--	--	--	--	--	1	1
Pacific sanddab	--	--	--	--	--	--	--	--	1	--	--	--	9	10
Slender sole	--	--	--	--	--	--	--	--	3	--	1	1	4	9
Rex sole	--	1	--	2	--	--	--	--	1	--	2	1	1	8
Showy snailfish	--	1	--	--	--	--	--	--	--	--	--	--	--	1
Bigfin eelpout	--	--	--	--	--	--	--	--	--	--	--	1	--	1
Unidentified rockfish	--	--	--	--	--	--	1	--	1	1	--	--	2	5
Unidentified snailfish	--	2	--	--	--	--	--	--	--	--	--	--	--	2
Unidentified fish	2	1	2	4	2	--	1	2	4	1	4	1	7	31
Unidentified material	1	--	--	--	--	--	--	--	1	2	--	--	--	4
Total number of stomachs examined	15	31	2	21	2	11	13	12	78	56	81	17	86	425
Number empty	3	8	0	13	0	11	8	2	19	9	54	8	37	172
Arrowtooth flounder size range (mm TL)	322–616	238–684	312–384	402–690	560–585	310–519	152–458	348–538	132–759	308–476	352–790	402–560	192–578	

* December samples from west of Eureka in 185 fathoms.
† February samples from west of Patricks Point in 380 fathoms.
‡ Megalops.

Pacific Hake

We examined 527 Pacific hake stomachs from July 1964 through September 1965 (Table 4). Seventy-seven (14.6%) were empty. The fish collected in December 1964 were captured by otter trawlers fishing west of Eureka in 109 and 185 fathoms.

Ocean shrimp were the most frequently observed organisms, followed by krill. Ocean shrimp made up 44.4% of the total volume, while the volume of krill amounted to only 18.5% (Table 5). Ocean shrimp were present in the stomachs every month of the study period. Slender sole, eulachon, Pacific tomcod, and Pacific sanddab were the most prevalent of the 12 species of fishes identified.

Highest average volumes were observed from August 1964 to March 1965.

DISCUSSION

Although northern California arrowtooth flounder and Pacific hake appear to feed primarily on crustaceans, their food habits probably depend on the availability of a particular organism. Stomachs from Pacific hake captured off Newport Beach, California, contained three

TABLE 3

Volume of Six Major Food Categories in Arrowtooth Flounder Stomachs Collected Off Northern California, September 1964–October 1965

Month	Volume (ml)							
	Ocean shrimp	Krill	Market crab	Misc. crustaceans	Fishes	Misc.	Total	Mean*
September	46.2	18.9	0.0	0.0	57.0	1.2	123.3	10.3
October	20.0	0.0	9.0	2.6	33.1	0.0	64.7	2.8
November	0.0	0.0	0.0	0.0	11.0	0.0	11.0	5.5
December	1.6	0.0	6.0	0.0	206.2	0.0	213.8	26.7
February	0.0	0.0	18.0	0.0	4.8	0.0	22.8	11.4
March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
April	1.0	0.7	0.0	1.0	51.0	0.0	53.7	10.7
May	33.0	11.5	0.1	3.7	6.4	0.0	57.7	5.8
June	60.5	42.7	0.0	11.5	56.1	1.0	171.8	2.9
July	208.7	17.9	0.0	25.0	1.6	T†	253.2	5.4
August	85.6	0.0	0.0	14.5	81.7	0.1	181.9	6.7
September	53.9	0.0	0.0	16.7	18.6	0.0	89.2	9.9
October	81.4	19.5	0.0	5.7	194.1	0.0	300.7	6.1
Totals	**591.9**	**114.2**	**33.1**	**80.7**	**721.6**	**2.3**	**1,543.8**	**6.1**
Percentage	**38.3**	**7.4**	**2.1**	**5.2**	**46.7**	**0.1**	**99.8**	

* Empty stomachs not included in calculations.
† Trace.

species of fishes and a single squid (Ferris, Ford, and Conway 1967). Best (1963) believes that Pacific hake are opportunistic feeders. The silver hake, *Merluccius bilinearis*, of the Atlantic evidently feeds heavily on shrimp and small fish (Fritz, 1962).

Studies of Pacific hake off Washington indicate that krill are the most important food of these fish, and may influence their vertical migrations during twilight and darkness (Bureau of Commercial Fisheries, 1967). The presence of krill in arrowtooth flounder stomachs during certain months may indicate that these fish also migrate towards the surface to feed. Studies of ocean shrimp vertical migration off Oregon suggest that they move toward the surface during darkness and return to the bottom at first light (Jack Robinson, Oregon Fish Commission, pers. comm.). This migration might also influence the vertical migration of arrowtooth flounder and Pacific hake.

I suspect that the Pacific hake and arrowtooth flounder off northern California are major predators on ocean shrimp, although the arrowtooth flounder does not seem to prey as heavily on shrimp as does the hake. Any future fishery for these two species may have considerable effect on the abundance and mortality rates of ocean shrimp.

TABLE 4

Frequency of Occurrence of 31 Organisms in Pacific Hake Stomachs Collected Off Northern California, July 1964–September 1965 *

Food item	Number of stomachs containing food item												
	July	Aug.	Sept.	Oct.	Dec.†	Mar.	Apr.	May	June	July	Aug.	Sept.	Totals
Polychaete worms	1	1	--	--	--	--	--	--	1	--	--	--	3
Squid	--	1	--	--	--	--	--	--	1	--	--	--	2
Channeled nudibranch	--	--	--	1	--	--	--	--	--	--	--	--	1
Squid	--	--	--	--	--	--	1	--	--	--	--	--	1
Isopods	--	1	--	--	--	--	1	--	--	--	--	--	2
Krill	11	31	22	11	3	--	37	21	36	37	15	7	234
Shrimp	5	1	2	13	--	1	10	--	1	--	2	2	37
Ocean shrimp	9	56	31	50	3	2	28	19	16	46	19	5	287
Hermit crab	--	--	--	1	--	--	--	--	--	--	--	--	1
Market crab	--	--	--	1	1	--	--	2	3	--	--	--	10
Pacific herring	--	--	1	--	--	1	--	--	--	--	1	1	4
Northern anchovy	--	--	--	--	--	--	2	--	--	--	--	--	2
Eulachon	--	3	--	--	--	--	1	4	1	3	--	--	12
Whitebait	--	--	--	2	--	--	2	--	2	--	1	--	7
Night smelt	--	--	--	1	--	--	--	--	--	--	--	--	1
Unidentified smelt	--	--	--	1	--	--	--	--	--	--	--	--	1
Deep sea smelt	--	--	--	--	--	--	1	--	--	--	--	--	1
Arrow dragonfishes	--	--	--	--	--	--	1	--	--	--	--	--	1
Idiacanthids	--	--	--	--	--	--	1	--	--	--	--	--	1
Lanternfish	--	--	--	--	--	--	1	--	--	--	--	--	1
Pacific tomcod	--	--	--	9	--	1	1	--	--	--	--	--	11
Pacific sanddab	--	--	--	7	--	1	1	--	--	--	--	--	9
Slender sole	1	--	1	6	--	--	4	--	1	--	2	2	17
English sole	--	--	--	--	--	1	--	--	--	--	--	--	1
Rex sole	--	--	--	4	--	1	2	--	1	--	--	--	8
Shiner perch	--	--	--	--	--	--	3	--	--	--	--	--	3
Unidentified flatfish	--	2	1	--	--	--	--	--	--	--	--	--	3
Unidentified rockfish	--	5	--	--	--	--	2	--	2	1	1	--	11
Unidentified sea poachers	--	1	--	--	--	--	--	--	--	--	--	--	1
Unidentified fish	--	5	--	10	2	--	6	--	1	1	1	1	27
Unidentified material	--	4	--	4	--	1	--	--	1	--	--	--	10
Total number of stomachs examined	**16**	**93**	**55**	**84**	**12**	**4**	**74**	**34**	**50**	**58**	**32**	**15**	**526**
Number empty	**0**	**18**	**13**	**11**	**6**	**1**	**5**	**4**	**7**	**4**	**5**	**3**	**77**
Pacific hake size range (mm TL)	184–633	177–815	100–714	436–729	418–702	690–748	410–680	402–658	407–614	408–686	462–764	418–742	

* Stomachs were not available during November 1964 or during January and February 1965.
† December stomachs were collected in 109 and 185 fathoms west of Eureka.

ACKNOWLEDGMENTS

This study was made possible by the assistance and cooperation of numerous people. Kim Ujito, David Hoopaugh, Donald Rinaldo, and Gary Varney assisted in collecting and examining the stomachs. John Fitch, Robert Lavenberg, and Richard Poole identified many of the fish and crustaceans found in the stomachs, and Jack Robinson provided the data on the Oregon Fish Commission vertical migration studies. I would also like to acknowledge the help of numerous commercial fishermen and the crew of the research vessel *N. B. Scofield* for their assistance in providing the fish involved in this study.

TABLE 5

Volume of Six Major Food Categories in Pacific Hake Stomachs Collected Off Northern California, July 1964–September 1965

Month	Volume (ml)							
	Ocean shrimp	Krill	Market crab	Misc. crustaceans	Fishes	Misc.	Totals	Mean*
July	18.1	47.7	0.0	8.8	2.8	0.5	77.9	4.9
August	495.1	147.3	0.0	1.2	115.1	2.3	761.0	10.1
September	207.7	112.6	0.0	6.1	126.0	0.0	452.4	10.8
October	548.2	77.4	69.0	150.4	576.7	8.2	1,429.9	19.6
December	7.3	27.7	8.3	0.0	73.0	0.0	116.3	19.4
March	17.0	0.0	0.0	2.0	140.0	95.0	254.0	84.7
April	168.8	118.4	0.0	25.8	232.5	1.0	546.5	7.9
May	147.7	56.0	4.3	0.0	32.1	0.0	240.4	8.0
June	48.0	188.6	1.3	1.0	41.3	0.6	280.8	6.5
July	408.8	142.8	0.0	0.0	13.2	0.0	564.8	10.4
August	150.5	55.8	0.0	4.7	132.7	0.0	343.7	12.7
September	131.0	5.2	0.0	13.1	66.3	0.0	215.6	18.0
Totals	2,348.2	979.5	82.9	213.1	1,552.0	107.6	5,283.3	11.7
Percentage	44.4	18.5	1.6	4.0	29.4	2.0	99.9	

* Empty stomachs not included in calculations.

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APPENDIX

List of Common and Scientific Names Used in Text and Tables

Common Name	Scientific Name
Polychaete worm	Polychaeta
Hermit crab	*Pagurus* sp.
Isopod	Isopoda
Krill	Euphausiacea
Market crab	*Cancer magister*
Ocean shrimp	*Pandalus jordani*
Shrimp	Natantia
Clam	Pelecypoda
Snail	Gastropoda
Squid	Cephalopoda
Brittle star	Ophiuroidea
Arrowtooth flounder	*Atheresthes stomias*
Bigfin eelpout	*Aprodon cortezianus*
Canary rockfish	*Sebastodes pinniger*
Channeled neptune	*Neptunea californica*
Chilipepper	*Sebastodes goodei*
Deep sea smelt	Argentinidae
Dover sole	*Microstomus pacificus*
Arrow dragonfish	*Tactostoma macropus*
English sole	*Parophrys vetulus*
Eulachon	*Thaleichthys pacificus*
Flag rockfish	*Sebastodes rubrivinctus*
Greenstripe rockfish	*Sebastodes elongatus*
Jack mackerel	*Trachurus symmetricus*
Lanternfish	Myctophidae
Night smelt	*Spirinchus starksi*
Northern anchovy	*Engraulis mordax*
Pacific hake	*Merluccius productus*
Pacific herring	*Clupea pallasii*
Pacific ocean perch	*Sebastodes alutus*
Pacific sanddab	*Citharichthys sordidus*
Pacific tomcod	*Microgadus proximus*
Petrale sole	*Eopsetta jordani*
Rex sole	*Glyptocephalus zachirus*
Rockfish	*Sebastodes* sp.
Sablefish	*Anoplopoma fimbria*
Sea poacher	Agonidae
Shiner perch	*Cymatogaster aggregata*
Showy snailfish	*Liparis pulchellus*
Smelt	Osmeridae
Snailfish	*Liparis* sp.
Speckled sanddab	*Citharichthys stigmaeus*
Spiny dogfish	*Squalus acanthias*
Stripetail rockfish	*Sebastodes saxicola*
Yellowtail rockfish	*Sebastodes flavidus*
Whitebait smelt	*Allosmerus elongatus*
Widow rockfish	*Sebastodes entomelas*

NOTES

EVIDENCE OF RIVER OTTER FEEDING ON FRESHWATER MUSSELS AND RANGE EXTENSION

River otters (*Lutra canadensis*) eat many species of aquatic vertebrates and invertebrates (Grinnell, Dixon, and Linsdale, 1937; Lagler and Ostenson, 1942; Geer, 1955; Hamilton, 1961; Sheldon and Toll, 1964). Extensive feeding on freshwater mussels, however, has not been recorded. In Santa Ana Creek, a tributary of the Pajaro River, 2.5 miles east of Hollister, San Benito County, California, signs of otter feeding on the mussel *Anodonta californiensis* were observed.

Several springs maintain year-round potholes of water in the upper Santa Ana Creek drainage. These springs serve as the only source of water for wildlife and provide environment in which aquatic organisms survive the annual dry season. Santa Ana Creek was dammed downstream from these springs approximately 18 years ago. The resulting body of water varies between 6 and 12 m in width, averages 2 to 3 m in depth, and is about $\frac{3}{4}$ mile long. Above the dam the banks are nearly vertical faces which exceed 12 m in height and are overgrown with annual grasses and herbaceous plants.

In the spring of 1967 a study of mussel fish hosts was initiated. This mussel, endemic to many California streams, parasitizes certain species of fishes for a brief period to complete its life cycle. An extremely high density of mussels exists in this water because damming of the creek impounded both the mussel and the host fish. Numerous shells and shell fragments were noticed intermittently along the west and east banks of the creek. Many of the shell remains had holes made by the teeth of an animal. A skull of a river otter had teeth which matched perfectly the premolar and molar patterns made in the shells (Figure 1). Skulls of various local carnivores did not.

One evening an otter was seen swimming at the surface briefly. The river otter was not expected in the area, since none has been reported south of San Francisco Bay and west of the Diablo Range of the Coast Ranges. It is unlikely that they have long been present in the Pajaro River drainage but have not been reported. More probably they recently crossed the Diablo Range from known areas of distribution in the San Joaquin River, some 45 miles to the east. River otters have accomplished extensive travels (McClellan, 1954) and have traveled overland from one drainage to another (Laughlin, 1955).

Extensive otter activity was noted. Forty-three landing sites along the creek banks had an average of 2.86 mussels, with a range of 1 to 6, per site. At least 123 mussels had been consumed. All shells and fragments had been deposited on the dry annual grass, indicating that feeding activity had occurred during the previous summer or fall. The largest intact shell was 75 mm in greatest length. The mussel shells which had

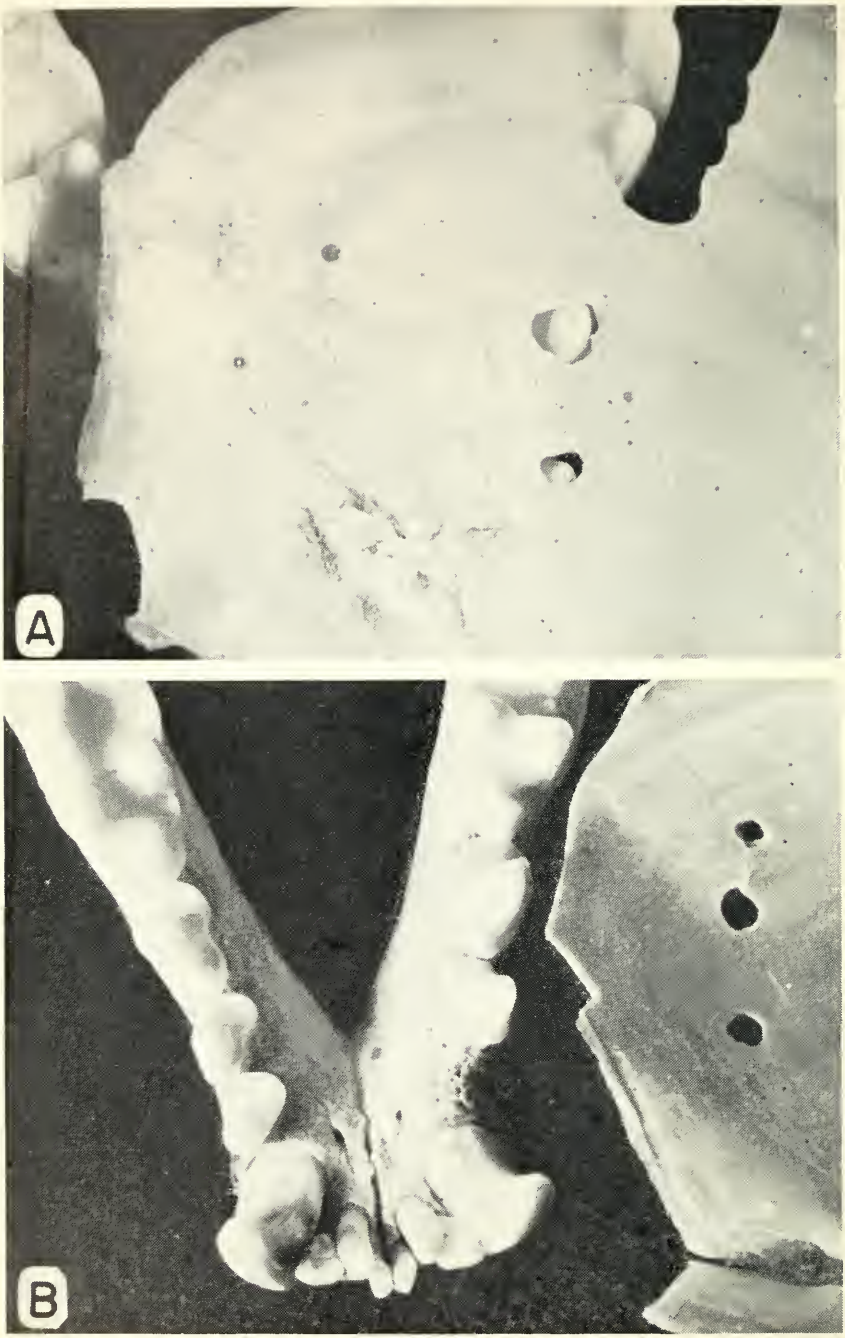

FIGURE 1—A, premolar and molar cusps of teeth in left mandibular ramus of the river otter (*Lutra canadensis*) shown aligned with holes in shell. B, the three holes in the mussel shell on right align perfectly with cusps shown on right ramus for last two premolars and paraconid of first molar. Note the hinge ligament on lower right below holes in shell. *Photograph by William E. Ferguson, February 1968.*

cusp patterns of cheek teeth in them indicated that they had been bitten from side to side, with the hinge or dorsal side away from the mouth of the otter, in most cases (Figure 1). Closer examination of the creek banks and environs revealed typical otter tracks, tail marks in mud, and trails pushed through aquatic vegetation.

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— *G. Victor Morejohn, Department of Biological Sciences, San Jose State College, San Jose, California.* *Accepted September 1968.*

AN ALLIGATOR SNAPPING TURTLE, *MACROCHELYS TEMMINCKII*, FROM CALIFORNIA'S INLAND WATERS

An alligator snapping turtle was found near Central Valleys State Fish Hatchery, Elk Grove, California, on January 1, 1968. Ernest Avery, a muskrat trapper, found the turtle lying dormant in the shallow water of an oxbow of Laguna Creek, adjacent to the hatchery grounds. He dragged it onto a levee and left it. Later in the day neighborhood boys saw it and clubbed it to death. They called a hatchery employee over to see it and it was subsequently placed in the hatchery freezer for identification and photographing (Figure 1).

This individual's carapace length was 18 inches (457 mm) and its width 15 inches (381 mm). It weighed 48 lb before freezing and appeared to be in excellent condition. It had been living in murky water teeming with a wide variety of warmwater fishes.

The alligator snapper is the largest of North American freshwater turtles and may reach a weight of over 200 lb. It is not native to California, although many small ones have been sold in aquarium shops. Undoubtedly some of these have been released into the wild when they had outgrown their containers or their owners had lost interest in them. However, this appears to be the first published note of its occurrence in the natural waters of California.

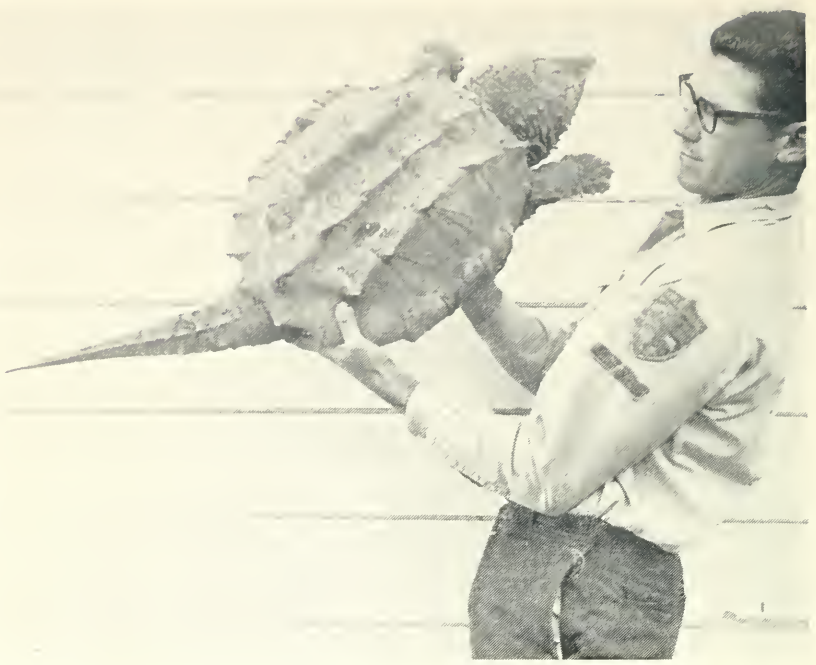

FIGURE 1—The author displays the turtle. *Photograph by Ray Dunham, January 1968.*

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—*Russell W. Murphey, Inland Fisheries, Region 2 (now with Wildlife Protection, Region 3), California Department of Fish and Game.*
Accepted May 1968.

A TECHNIQUE FOR PRODUCING AND MOUNTING OTOLITH WAFERS FOR AGE DETERMINATION

Wafers (sections) of fish otoliths frequently offer the only reliable way to determine age, but since the cost of producing wafers is greater than the cost of processing scales or whole otoliths, they should be resorted to only as a check on other "aging" methods or if reliable alternatives are not available.

"Wafering" for age determination is required when otoliths cleared in anise oil or other agents are too opaque to read, when precipitous marginal escarpments prevent observation of the most recent rings, and when the density of rings prohibits accurate counting.

The mounting technique described herein was developed for use primarily with a hydraulically controlled, gravity down-feed, diamond

cutoff wheel, but it is equally useful if the cutting is to be done on a lapidary trim saw. The 4- × 0.012-inch continuous rim cutoff blade is oil cooled while rotating at 3,200 surface ft per min.

For cutting orientation, the side opposite the grooved inner face of the otolith is marked from edge to edge through the nucleus. The best sections are obtained by cutting through the otolith nucleus along the longitudinal axis or through its perpendicular (Figure 1). These sections will show the growth rings approximately at a right angle from the face of the cut (the effect is similar to what one would see in looking at an open Venetian blind).

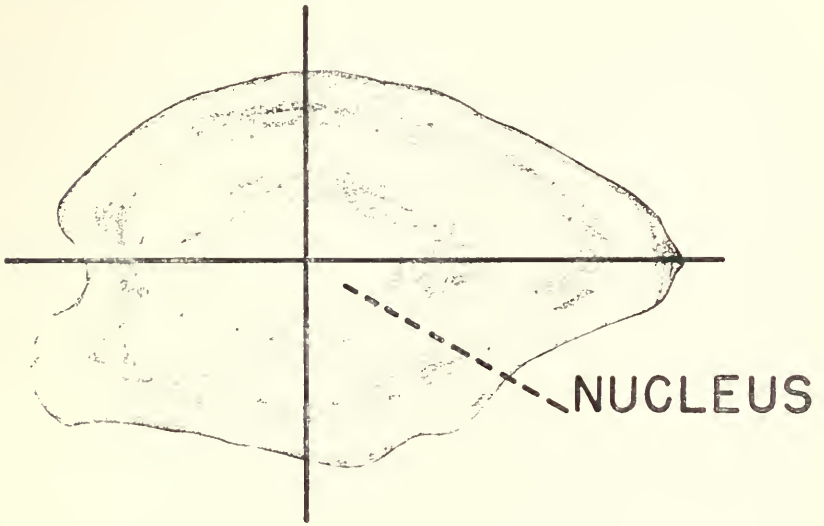

FIGURE 1—Drawing of an otolith showing the best cutting axes for wafers used in age determination.

Dental Impression Compound (Kerr No. 2, soft green) having a low melting point (123 F) is used to affix the otolith to a 1- × 1- × 2-inch pine block. This mounting medium reduces the number of heat-cracked otoliths, and can be shaped and molded with the fingers while still plastic. Frequent moistening of the fingers on a damp towel will prevent the hot compound from adhering and burning.

The face of the pine block is heated over a Bunsen flame to a point where the compound will melt and flow on to the surface of the block. This insures a good bond. Additional compound (three or four times the otolith volume) is added and heated until it is soft and pliable, but not liquid. The otolith is then positioned and pushed into the compound, which is then molded over the otolith's edges to encapsulate all but the orientation pencil mark (Figure 2).

When the compound cools, four or five 0.010- to 0.015-inch-thick wafers are cut, each including a segment of the nucleus. Next, the wooden block with the wafered otolith is immersed in warm water to soften, but not melt, the compound. In sequence, each wafer then is loosened with a dissecting needle and placed in toluene for cleaning with a bobtailed No. 2 camel's hair brush.

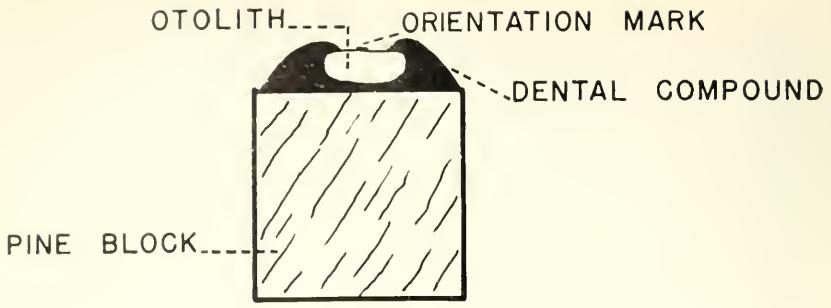

FIGURE 2—Diagram of a cross section of an otolith mount ready for "wafering".

The cleaned sections are removed from the toluene, and while still damp (not dripping wet), mounted on a microscope glass slide that is coated with a thin layer of Sears Roebuck & Co. clear automotive windshield sealer. This sealer holds the wafers firmly, does not crack or craze, and does not require a sealed cover glass. No deterioration of this sealer has been noted during 3 years of storage. This adhesive is excellent for dry mounting other small specimens.

Fish spines and portions of mollusk shells also have been wafered by this technique.

—*Jack W. Schott, Marine Resources Operations, California Department of Fish and Game. Accepted April 1968.*

THE FILETAIL CATSHARK, *PARMATURUS XANIURUS*, IN MIDWATER IN THE SANTA BARBARA BASIN OFF CALIFORNIA

Nearly all the information about the depth habitat of the 50 or more species of catsharks, family Scyliorhinidae, known throughout the world has been derived from captures made by otter trawls dragged on or near the bottom. Some of these captures may have been made in midwater while the nets were being lowered to the bottom or while they were being retrieved to the surface; nevertheless, the preponderance of data now available shows that catsharks occur at or near the bottom. However, small filetail catsharks recently have been taken in midwater trawls in the Santa Barbara Basin off California. Whether other species in this famly also frequent waters some distance above the bottom remains unknown.

During the years 1964–1968, the General Motors research vessel *Swan* [1] conducted experimental trawling operations in the Santa Barbara and Santa Cruz Basins utilizing an Isaacs-Kidd self-closing midwater trawl. This net had an aperture of 5 ft 9 inches by 4 ft 8 inches, and a length of 25 ft 10 inches from the gape to the cod end (Aron et al., 1964). While invertebrates and many species of mesopelagic fishes were captured, the shark fauna was represented only by the filetail catshark. While the brown catshark, *Apristurus brunneus*, occurs

[1] Work done under the auspices of National Science Foundation Grant GB–4698.

in the Santa Barbara and Santa Cruz Basins, and the area is within the known range of another member of the family, *Cephaloscyllium ventriosum*, neither species was taken by the *Swan*.

Since the filetail shark has been considered a demersal species, it is of interest that small filetail sharks were taken at distances up to 1,604 ft above the sea bottom (Table 1) along with such mesopelagic fishes as *Lampanyctus*, *Diaphus*, *Argyropelecus*, *Leuroglossus*, and *Cyclothone*. There is no indication that mature filetail sharks (415 mm and greater) occur in midwater; however, the relatively small size of the Isaacs-Kidd trawl may have precluded capture of the larger sizes.

TABLE 1

Depth of Filetail Catshark Captures by the *Swan* in the Santa Barbara Basin *

Swan Log no.	Date	Depth of bottom (ft)	Depth range of tow (ft)	Minimum distance from bottom (ft)	Number of filetail catsharks	Standard length (mm)	Sex
1002–2	Aug. 13, 1964	1,728	855–surface	873	2	220–280	
1006–1	Aug. 21, 1964	1,800	957–898	843	2	207–242	
1008–1	Aug. 21, 1964	1,890	1,716–1,386	174	1	170	
1011–2	Nov. 18, 1964	1,890	1,581–surface	306	7	180–223	
1023–2	Dec. 16, 1964	1,884	1,670–330	214	1	145	♀
1023–4	Dec. 16, 1964	1,806	330–surface	1,476	2	196–240	♂♂
1021–2	Jan. 12, 1965	1,860	1,723–surface	137	1	210	
1033–2	Feb. 16, 1965	1,800	1,709–surface	91	1	198	
1043–2	Mar. 3, 1965	1,860	1,766–surface	91	2	190–200	
1054–2	April 14, 1965	1,908	1,792–1,170	116	1	138	
1057–1	May 18, 1965	1,890	1,703–1,650	187	1	200	
1057–2	May 18, 1965	1,890	1,650–1,155	240	1	224	
1063–1	May 19, 1965	1,881	1,716–1,676	168	1	142	♂
1063–2	May 19, 1965	1,890	1,676–1,155	214	1	148	♂
1065–1	June 29, 1965	1,908	1,723–1,670	185	2	117–250	
1065–3	June 29, 1965	1,908	1,155–surface	753	1	150	
1071–2	June 30, 1965	1,908	1,806–surface	102	1	320	
1075–1	July 27, 1965	1,902	1,707–1,577	195	4	144–263	
1075–3	July 27, 1965	1,860	1,468–1,155	392	1	380	♂
1081–2	July 28, 1965	1,890	1,656–1,468	234	3	171–310	♂♀♀
1084–2	Aug. 17, 1965	1,908	1,690–1,155	218	1	200	♂
1081–3	Aug. 17, 1965	1,860	1,155–660	705	1	181	♀
1091–2	Sept. 28, 1965	1,770	1,739–990	31	1	140?	
1099–2	Sept. 29, 1965	1,800	1,716–974	84	1	208	
1099–3	Sept. 29, 1965	1,710	974–403	766	1	130	
1206–1	July 6, 1966	1,890	1,785–1,574	105	4	140–275	
1206–2	July 6, 1966	1,890	1,785–693	105	2	170–170	
1206–3	July 6, 1966	1,884	693–280	191	2	170–170	
1209–2	Aug. 29, 1966	1,894	1,657–924	237	1	124	
1209–4	Aug. 29, 1966	1,884	280–surface	1,604	2	164–210	
1264–1	April 3, 1967	1,890	1,574–1,620	270	2	129–150	
1264–2	April 3, 1967	1,896	1,620–1,003	276	1	273	
1264–3	April 3, 1967	1,878	1,003–858	875	1	230	
1264–4	April 3, 1967	1,836	858–surface	978	1	230	♂
1271–1	May 2, 1967	1,842	1,442–1,458	384	1	115	♂
1271–3	May 2, 1967	1,878	950–950	928	2	99–116	♂♂
1278–1	July 10, 1967	1,902	1,650–1,690	212	3	113–201	♂♀♀
1278–2	July 10, 1967	1,860	1,690–855	170	2	188–246	♂♀
1278–3	July 10, 1967	1,818	858–858	960	1	171	
1285–2	July 31, 1967	1,902	1,746–947	156	2	173–207	♂♂
1285–3	July 31, 1967	1,902	947–944	955	1	225	♂

* All hauls made in the Santa Barbara Basin between 10:55 a.m. and 11:40 p.m.

Based on data made available by Gregory Cailliet, University of California at Santa Barbara, this species was taken in 43 hauls varying from 31 to 1,604 ft above the sea bottom. Of the 22 specimens that I examined, 7 were females, ranging from 145 to 310 mm SL, and 16 were males, ranging from 99 to 380 mm SL.

ACKNOWLEDGMENTS

I wish to thank Stewart Springer, U.S. National Museum, for his help and suggestions in preparing this note, and Gregory Cailliet, University of California at Santa Barbara, for supplying specimens and data.

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—*Richard S. Lee, Santa Barbara Museum of Natural History.* *Accepted May 1968.*

ADDITION OF *PYLODICTIS OLIVARIS* TO THE CALIFORNIAN FAUNA

Four young-of-the-year flathead catfish were collected by the authors in the Highline Canal and its tributaries, near Niland, Imperial County, approximately 4 miles east of the Salton Sea, during January and February 1968, as follows: January 31, 145 mm TL, 30 g; February 7, 122 mm TL, 16 g; February 15, 216 mm TL, 91 g; February 26, 221 mm TL, 99 g. This is the first verified record of flathead reproduction in California.

These catfish were originally introduced into the Colorado River by the Arizona Game and Fish Department in March 1962. Approximately 600 fish averaging 10 inches in length were planted in six areas of the river, including Clear, Martinez, and Ferguson Lakes. All plants were made above Imperial Dam.

The probable route of flathead catfish into Imperial Valley was downstream to the Imperial Dam, thence into the All American Canal system.

On the basis of the collected specimens, we conclude that flathead catfish are established in Imperial County.

—*Lawrence Bottroff, James A. St. Amant, and Wayne Parker, Inland Fisheries, Region 5, California Department of Fish and Game.* *Accepted September 1968.*

BOOK REVIEWS

Flora of Alaska and Neighboring Territories: A Manual of the Vascular Plants
By Eric Hultén; Stanford University Press, Stanford, Calif., 1968; xxiv + 1008 + 8 p., profusely illustrated. $35.

This monumental work describes and excellently illustrates all flowering plants and vascular cryptogams known to occur in Alaska, the Yukon, the Mackenzie District, and the eastern extremity of Siberia. The inclusion of the latter helps to clarify the important overlapping of the floras of the two continents.

The author, Director Emeritus of the Botanical Department of the State Museum of Natural History in Stockholm, has published extensively and authoritively on Arctic floras. The present book is the painstaking culmination of close to fifty years of study of circumpolar floras.

Some 1,974 taxa, belonging to 1,559 species, 412 genera, and 89 families, are described. For 1,735 of these, there are detailed descriptions, nomenclature, plant drawings, and both Alaska and circumpolar range maps. The latter, the first to be used in a major flora, provide valuable insight into the geographical affinities of the flora. There are also eight pages of color photos by the author.

In addition to morphologic features, the plant descriptions include typical habitat, economic importance (especially as food), toxicity, and other information of interest.

Dichotomous keys based on physical characters are provided for the major groups of plants, the families making up each major group, the genera making up each family, and the taxa making up each genus. The use of these keys in conjunction with the plant drawings and the plant and habitat descriptions should make it possible to identify any plant occurring in the area covered.

The Introduction describes the past and present climatic, geologic, and ecologic character of the area, the history of botanical collection there, and the author's treatment of botanical and taxonomic details. It also lists plants of neighboring regions likely to occur.

The book is completed with a glossary, a list of all taxon authors appearing in the book, a list of persons for whom taxa have been named, bibliography, and indexes to common and scientific names. The author lists include brief biographical data and emphasize the extensive study devoted to the flora of this region.

Not all botanists will agree completely with the author's taxonomic treatment, for concepts of species and genera inevitably vary; nevertheless, his book represents a major contribution to our knowledge and understanding of the biogeography of Alaska, crossroads of past migrations between two continents and two oceans.—*Leo Shapovalov.*

Poisonous Plants of Hawaii
By Harry L. Arnald; Charles E. Tuttle Co., Rutland, Vermant, 1968; 71 p., illustrated with line drawings. $2.50.

Manual of Wayside Plants of Hawaii
By Willis T. Pape; Charles E. Tuttle Co., Rutland, Vermont, 1968; 289 p., illustrated. $6.

Farming the Edge of the Sea
By E. S. Iverson, Fishing News (Books) Ltd., London, 1968; 301 p., illustrated. £4 5s. 0d. Available in U.S. from National Fisherman, 22 Main Street, Camden, Maine 04843. $10 postpaid.

Even as our yen for knowledge of outer space accelerates, a counterwave of interest in an increased knowledge of the waters of our continent is being developed. In recent years, many wild claims about the potential yield of the seas have been made, and many wild schemes developed for harvesting the seas' bounty. In this book Dr. Iverson has set about to dispel some of the myth of the inexhaustible sea and to discuss frankly what propagation methods are practical and what are not practical in various areas of the world.

The author is an Associate Professor at the Institute of Marine Science, University of Miami, Florida, and, although a practicing scientist, has written a book that will be of interest and informative to both scientist and layman. Dr. Iverson is well

equipped to assess accurately the potential for farming the sea by having worked and studied in many temperate and tropical areas of the world. He has investigated the biology of shrimp, lobster, and sea trout, and many other forms, and has conducted surveys in the Caribbean and South America.

Most people who are interested in sea farming are motivated by the money-making aspects. This book outlines procedures for getting into the aquaculture business, and describes the many species of fish, shellfish, and plants that are currently being farmed, such as oysters, shrimp, clams, mussels, mullet, milkfish, and even seaweed. The author warns of the potential pitfalls and failures that may occur in sea farming, and ways in which they may be avoided. For the neophyte sea farmer, the author has included an operational check list prepared by the Bureau of Commercial Fisheries for freshwater farming which may be applied to sea farming as well. The author stresses that by assessing all practical aspects of a sea farming venture at the start, including financing, physical features, biology, etc., the chance of failure will be reduced.

One chapter is devoted to describing the species with the greatest potential for future cultivation. Most of the potential species discussed, such as the American and spiny lobsters, have a high market value, which encourages interest in farming them, but it is pointed out that knowledge to rear them profitably on a commercial scale is presently lacking.

The book is not intended to be used as a handbook, but the clear photographs and descriptive text, coupled with an extensive glossary and bibiography, make it an excellent reference on aquaculture. The pictures in the book are all of excellent quality, but their usefulness could have been increased if many of them had been more descriptive of the material they were intended to cover.

Farming the Edge of the Sea is the most up-to-date book of its kind on the market today. Any person who is contemplating going into marine aquaculture, and even those already in the business, will find the book both interesting to read and a welcome addition to his library.—*Emil J. Smith, Jr.*

The Biology of Populations

By Robert H. MacArthur and Joseph H. Connell; John Wiley & Sons, Inc., New York, 1966; xv + 200 p., illustroted. $6.95.

This book is intended as "part of a demanding introductory biology course". The authors describe a number of basic concepts of population dynamics and relate them to the process of evolution and to general patterns in the environment. They regularly raise interesting and useful questions and if the answers are not often available they do a good job of describing interesting hypotheses. The book covers a broad subject. It is saved from being only a text by a large number of unusual analogies and stimulating examples from the literature.—*Don W. Kelley.*

California Mission Recipes

Adapted for modern usage by Bess A. Cleveland; Charles E. Tuttle Co., Inc., Rutland, Vermont, 1965; 141 p., illustroted. $2.75 (paper).

California Mission Recipes is a unique cookbook which will appeal to the student of California history as well as to the housewife concerned with planning special dishes for her family. The simple, practical recipes are adapted from those used by the Franciscan Fathers and their followers during the heyday of the California missions. For the most part, they reflect the availability of foodstuffs produced on lands adjacent to the missions and the fish and wildlife found in the area. Fortunately, the author has converted some of the original rather obscure measurements and procedures into more understandable terms. The reader will probably wish to try many of the recipes of the everyday variety. Less apt to be used, but nevertheless very interesting, are instructions for making such products as wine, cheese, olive oil, and yeast. The recipes are assembled in 21 groups, each of which is preceded by photographs and a brief history of one of the missions.—*George H. Warner.*

A Sand County Almanac and Sketches Here and There

By Aldo Leopold; Oxford University Press, New York, 1968; xiii + 226 p., illustrated. $1.75; in Canada $1.95 (paper).

Another edition of *A Sand County Almanac* was reviewed in the January 1968 issue of *California Fish and Game.*—*Editor.*

Human Influences on the Zoogeography of Panama

By Charles F. Bennett; University of California Press, Berkeley and Los Angeles, 1968; vii + 112 p., 8 maps. $3.50 (paper).

The Atlantic Salmon: A Vanishing Species?

By Anthony Netboy; Houghton Mifflin Co., Boston, 1968; 457 p., illustrated. $6.95.

Anthony Netboy has done a commendable job in preparing this book. He made an extensive review of the literature, travelled over 15,000 miles to 10 European countries, and consulted with numerous experts to gather material. The result is a book that should stimulate interest in protecting "one of the noblest and most honoured of fishes known to man".

The author describes the evolution of this fish, its life cycle and migrations, and the history of salmon fisheries from earliest recorded times to the present throughout its original range. Vivid descriptions of the rivers and surrounding countrysides enhance the various chapters.

The fate of Atlantic salmon in Spain, France, the Baltic countries, Norway, Iceland, Greenland, United States, and Canada is recounted. The careless disregard for this fish, both by overfishing and destruction of the habitat, is clearly portrayed. The fact that the United States has frittered away its Atlantic salmon resource as wantonly as any other country is no source of pride.

Measures that are being taken to preserve existing resources, and possibilities for helping this species to recover in areas where it has been decimated, are outlined. One can only hope that the public will become aroused enough to force action that will help to preserve *le Saumon de l'Atlantique*.

This book is written in a popular style that should appeal to all who are interested in our dwindling natural resources. It contains a message of how our resources can be abused, and points out the need for education and cooperation to protect those that are being seriously diminished. It should be required reading for all conservation administrators.—*Leonard Fisk.*

Sea Otters and the China Trade

By Robert Kingery Buell and Charlotte Northcote Skladal, David McKay Company, Inc., New York, 1968; xii + 212 p. $4.50.

The history of the sea otter fishery, the influence this fishery exercised upon the development of the West Coast, and the people who pursued this inimitable furbearer to near extinction are traced. Proceeding from the voyage of the *H.M.S. Resolution* under Captain James Cook to the Pacific Northwest coast in search of the fabled Northwest Passage; to the Aleutian Islands where Captain Cook learned of the Russian, Vitus Bering, who had already discovered the valuable sea otter; then to the development and expansion of the sea otter fishery into California and Baja California; and finally through the ultimate decline and failure of the fishery, the authors vividly unfold the events.

The development of trade routes to China is described. Sea otter pelts brought fabulous sums in China because of the status symbol they represented to the mandarins.

The book is not free of questionable statements and typographical errors. For example, in reference to the Spanish constructing a mission to block the Russian advance in California, the mission location is listed as "Sonora" instead of "Sonoma". The description of American merchantmen wading through bulrushes and mud at the edge of Monterey harbor in order to visit the presidio appears faulty. Bulrushes do not occur along the sandy or rocky stretch of coastline adjacent to the Monterey Presidio and it is highly doubtful that they ever did.

Despite these and other trivial errors, Robert Buell and Charlotte Skladal have adeptly blended historical information about a fishery and the early settlement of the Pacific Coast and, indeed, have elevated the sea otter to an unparalleled factor in this settlement—even exceeding that of the discovery of gold in California.

Easily read at one "sitting" and recommended to all.—*Earl E. Ebert.*

A Flora of Kern County, California

By Ernest C. Twisselmann; the University of San Francisco, San Francisco, Calif., 1967; 395 p., illustrated. $6.

This book is essentially in two parts. The first describes the natural history of the plants in Kern County, including discussion of the various environmental factors affecting plant distribution, such as climate, geography, soils, geology, and land use. Seventeen plant associations are described. Sixty-eight photographs show the general aspects of the vegetation. The second part, the appendix, is a listing

of all plants known to occur in the county. For each plant listed there is a discussion of its distribution and occasionally other data of interest are provided.

This book is not a field manual for identification of plants but rather a supplement to be used in conjunction with various available field manuals.

Floras of local areas, such as this, are very useful to botanists and range, forest, and wildlife managers, since they provide detailed information impossible to include in works covering the State or larger geographic areas. It would be nice if more such publications were available.

An interesting point is that the author is a nonprofessional botanist, although he worked closely with professionals in compiling this work.

This flora appeared first in the Wasmann Journal of Biology and has been reprinted from that source.—*C. M. Ferrel.*

The Biological Basis of Freshwater Fish Production

Edited by Shelby D. Gerking; John Wiley & Sons Inc., New York, 1967; xiv + 495 p., illustrated. $15.

The unifying theme of the symposium which this book reflects was fish production, in the strictly ecological sense—"The total quantity elaborated over a stated period of time regardless of whether or not all of it survives to the end of that time". The 20 chapters, by as many authors, contain much information of interest and value to fisheries workers. However, they suffer the usual deficiencies of symposia in falling short of a coherent treatment of the theme. In fact, the individual contributions differ so greatly in subject matter and approach that the volume resembles an unusually thick issue of a technical journal more than a book and is correspondingly difficult to review.

The individual papers fall into the general subject areas of vital statistics of fish populations, relation of fish populations to their food supplies, competition and behavioral factors influencing production, predation and exploitation by man, and the contribution of freshwater fish production to human nutrition and well-being. Specialists in the various fields will find the extensive literature reviews and bibliographies valuable. More casual readers are apt to find much of the book heavy going.—*Alex Calhoun.*

Fishing with Electricity: Its Application to Biology and Management

Edited by R. Vibert; Fishing News (Books) Ltd., London, 1967; xxviii + 276 p., illustrated. £3 12s. 6d. Available in U.S. from National Fisherman, 22 Main Street, Camden, Maine 04843. $9 postpaid.

This book presents the proceedings of a symposium on electrofishing held in 1966 by the European Inland Fisheries Advisory Commission, a subsidiary body of FAO. Symposium contributors included electrical engineers, biologists, and electrophysiologists.

The first section of the book is a general report of a working party which summarizes the symposium. The second section contains the papers presented and is grouped into the following categories: electrophysiology of fish, electric fishing practice and its efficiency, electric screens and guides, and miscellaneous papers.

A great deal of useful information is contained in the book but, like many symposiums, it becomes repetitious, with several contributors reporting on similar experiments and similar findings. Had the editor summarized the symposium into a textbook on electrofishing, instead of a compilation of symposium papers, it would have been more interesting reading. Nevertheless, the book has a good deal of value to those interested in electrofishing and the electrophysiology of fishes.—*James W. Burns.*

Mammals of Southern California

By Ernest Sheldon Booth; University of California Press, Berkeley and Los Angeles, 1968; 99 p., illustrated. $1.75 (paper).

This is another in the "California Natural History Guides", published by the University of California Press. This guide is designed for the amateur naturalist or person interested in learning more about the mammals native to southern California. This guide is light in weight and will fit handily into an automobile glove compartment.

The illustrations are adequate but it would be helpful to the beginner if the black-and-white illustrations were labeled.

I believe the white-tailed hare should be included, since it extends into Inyo County.

The account of the pronghorn is erroneous. There are a few pronghorn along the California-Nevada border in Mono County, but no authenticated occurrence of pronghorn in the area covered by this book has been recorded for more than 30 years.

In spite of these shortcomings the book in general is interesting and informative. It gives information on where to find the various mammals and how to collect and preserve mammal specimens. The readers, however, are not cautioned that a scientific collecting permit must be obtained if a person wishes to collect species other than nonprotected mammals. In addition, capture of baby skunks should be discouraged because of the danger of rabies.—*Wallace G. Macgregor.*

Desert Wild Flowers

By Edmund C. Jaeger, Stanford University Press, Stanford, California, 1968; xxx + 322 p., illustrated. $2.95 (paper).

Desert Wild Flowers is a field guide measuring approximately 8½ by 5½ by 1 inches in size. It includes all known plants in the California deserts and is uniquely designed to acquaint readers with desert flora. Many desert plants are illustrated for the first time. The guide also contains about 2 dozen black-and-white photographs and 764 line drawings—one for each plant described.

The author recommends using colored pencils to color each line drawing directly from the plant as it is encountered in the field. This is intended to impress the various plants in the reader's memory.

The 73 families in the guide are arranged systematically by scientific name, and there is a good explanation of what the scientific names mean—very importantly, common names also are included. In the discussions following the various families and species, the author presents a lot of interesting natural history and other pertinent information, such as accounts of early desert explorers and botanists who are commemorated in the plant names, present and past uses for the plants, kinds of areas in which they grow best and unusual botanical features.

It was frequently necessary to use flower color as a key character in the plant identifications. This means that the identification key can be used to best advantage during late winter and spring, when most desert plants are blooming.

The author claims that this field guide will prove useful to the professional botanist and amateur as well as to travelers and out-of-doorists. In my opinion, the guide will prove very valuable to the professional and amateur botanist, but the traveler and out-of-doorist will find the plant identification keys somewhat difficult to use because space limitations permitted only a limited glossary.

This guide is well worth the price, and it should be standard equipment for all desert lovers.—*Harold B. Clemens.*

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